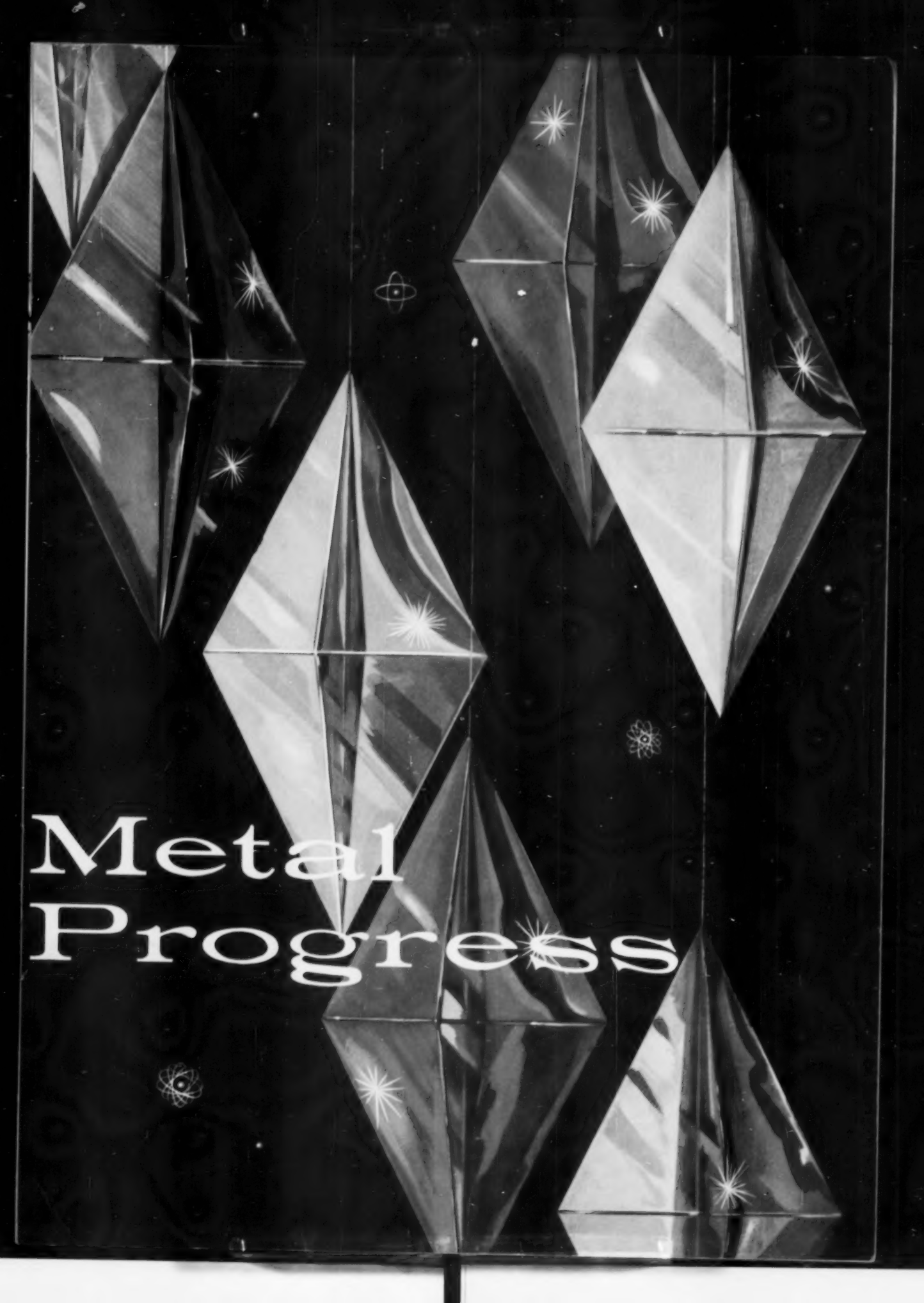
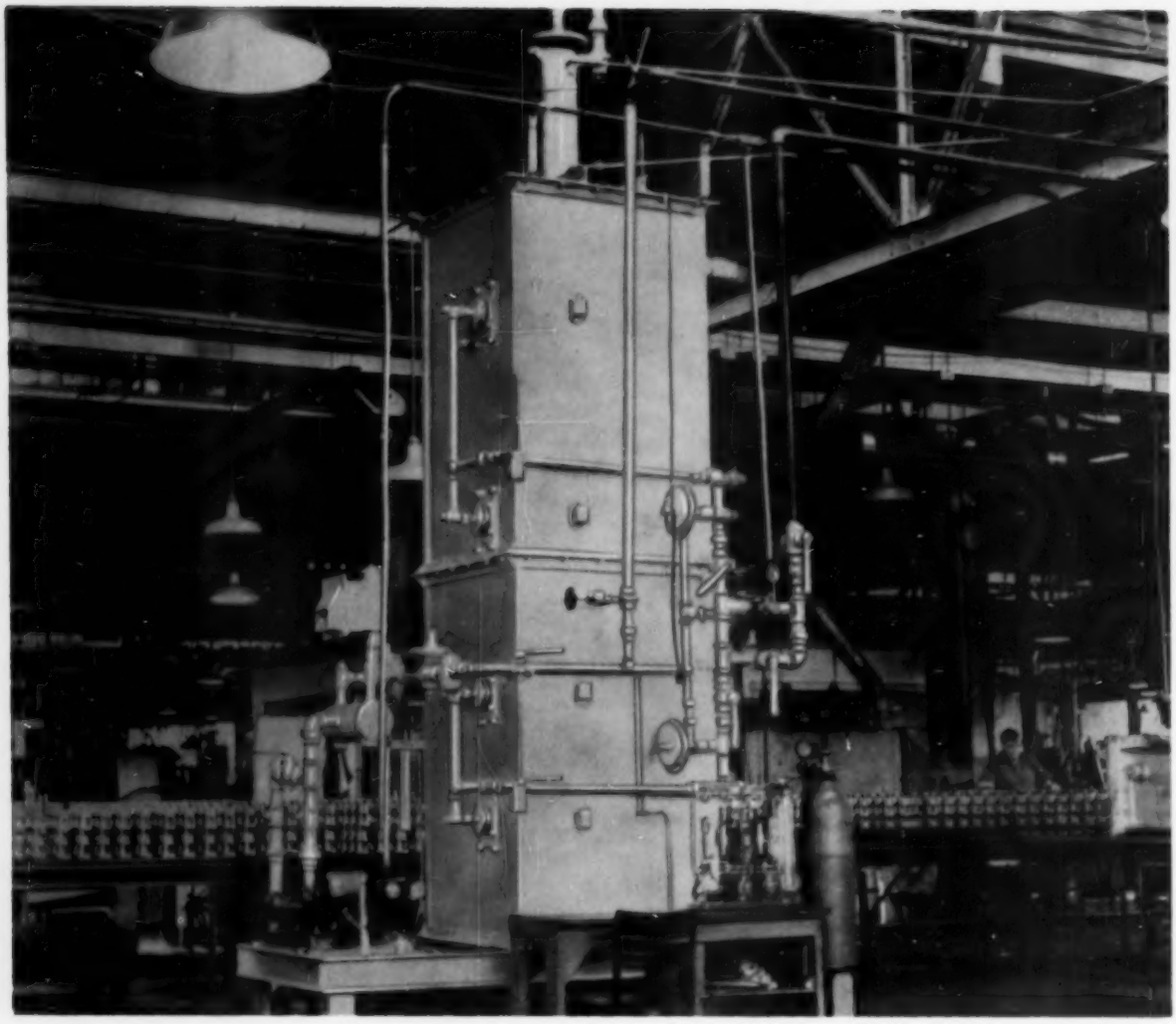

Metal
Progress



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Metal Progress

Volume 70, No. 6

December . . . 1956

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Christmas Cover by ROBERT C. FULTON

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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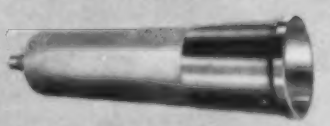

Thermalloy octagonal retort

Thermalloy pit-type retort and basket

Thermalloy shaker hearth muffle

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
Elyria, Ohio

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As I was saying...

A VERY UNUSUAL INCIDENT happened to me during the Metal Congress and Exposition while I was going the rounds to see the exhibits and to say hello to many of my friends whose paths crossed mine. I was in the lower level looking at the Gas Exhibit, which since 1925 has been the largest combined exhibit in the Metal Show. It was my good fortune to run into Phil Osterman, now president of the American Gas Furnace Co. of Elizabeth, N. J., and close family friend of nearly 40 years. I sure was glad to meet him and in only a few seconds we were in deep reminiscences. Then all of a sudden we heard someone yell, "There's a bear behind!" I was shocked and so was Phil, and as we glanced up to see the announced unusual phenomenon we were blinded by a floodlight and had to raise a hand to shade our eyes. Then a flash bulb exploded almost in our faces and we were blinded further. By the time our eyes were adjusted to regular light they handed us the picture that heads this column and sure enough there was "A Bear Behind" — a big 900-lb. Kodiak — and so everybody laughed because while Phil and I know how to spell we had unfortunately misinterpreted the spoken word.

"Look at That Bear Behind!"

It was a great Congress and Exposition. The technical sessions were all tops in quality and capacity in attendance. Most meetings were S.R.O. The Show filled every niche in the massive auditorium — the largest show ever in Cleveland, ever to use the Hall, and ever put on by A.S.M. There were 42,708 registrants and 68,379 clocked attendance. And one thing that makes us feel so happy is the congratulatory letters we are receiving telling how successful it was for the exhibitors. Even the hotels (all of them) wrote it was the best business week they had ever experienced.

Now we are busy getting floor plans ready to send out for the Chicago Convention and Metal Show Nov. 2 through 8, 1957. And as though the Congress and Exposition were not enough, the Second World Metallurgical Congress will be held at the same time in Chicago. More than 350 conferees from 31 countries have already notified us they will attend and undoubtedly many more will come.

And just as though that was not enough to keep us hopping, we are now head over heels with the Los Angeles Chapter in preparation of the program for the Western Metal Congress in Los Angeles next March 25 through 29. And in addition — the Western Metal Exposition, to be held simultaneously with the Congress, has been sold out. It will be the largest show we have ever held in the West (it's one-half the size of the National Show) so you can realize the great industrial developments of the West.

I hope you all had turkey for Thanksgiving and many, many things for which to give thanks. And may there be another turkey in your deep freeze for the Christmas dinner. When all is said and done there are many things for which to give thanks, not only at Christmas but every day; to be with your loved ones; to have health and happiness for your family and self, and to have friends. Yes, other than our families—friends are our most precious asset.

For you and yours, may every day be full of Thanksgiving and the Christmas spirit — is the sincere wish of your friend,

Bill

W. H. EISENMAN, *Secretary*
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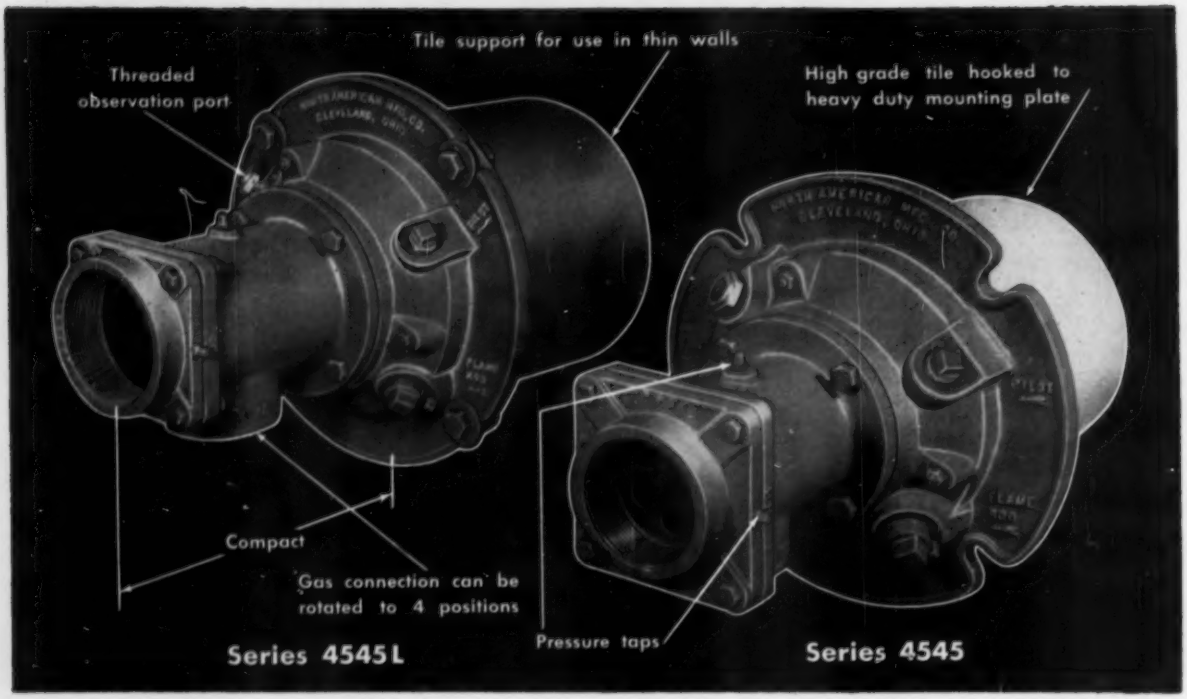
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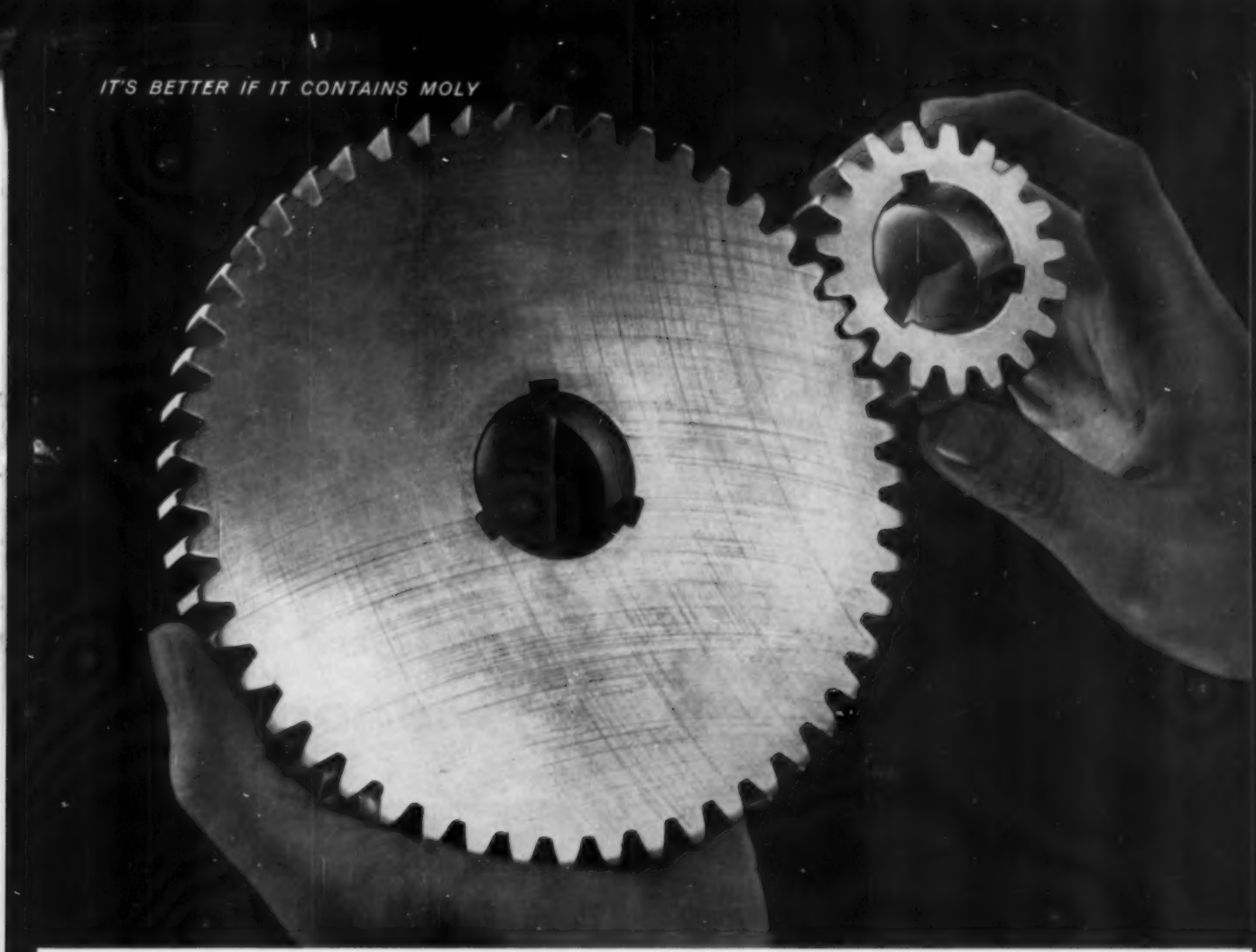

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Why limit the use of molybdenum to the .15/.25% Mo and .20/.30% Mo contents of the traditional grades? For the contributions of moly do not stop there. Laboratory tests and production runs prove that as molybdenum contents increase up to 1%, hardness increases progressively. A wide range of case and core hardenabilities, therefore, can be obtained – economically, too.

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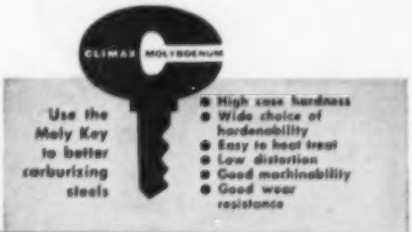
If you use carburizing steels, see what a higher molybdenum content can do for you. Part of the story is contained in the technical article "New Carburizing Steels For Critical Gearing." For your copy, or other technical data, write Climax Molybdenum Co., Dept. 5, 500 Fifth Avenue, New York 36, N. Y.

CLIMAX MOLYBDENUM



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The tools shown at left were made from Republic 4140 Hot Rolled Alloy Steel Bars by The Cornwell Quality Tools Company, Mogadore, Ohio. This manufacturer has used alloy steels for more than 30 years.

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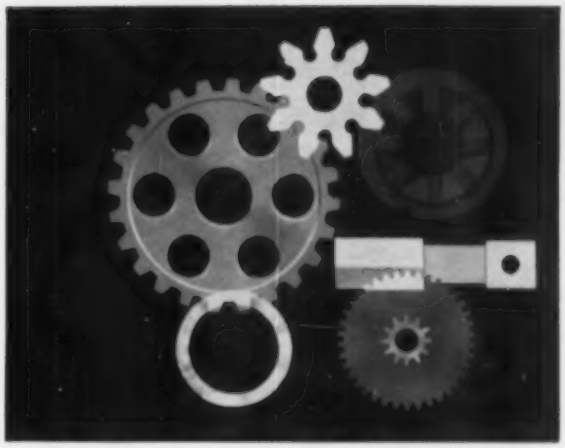

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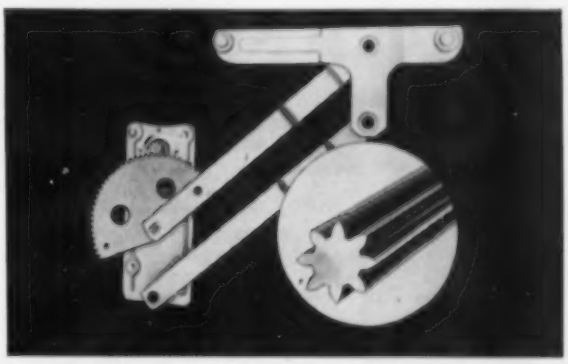

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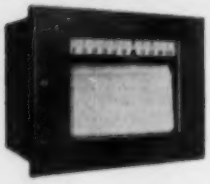

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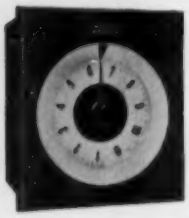

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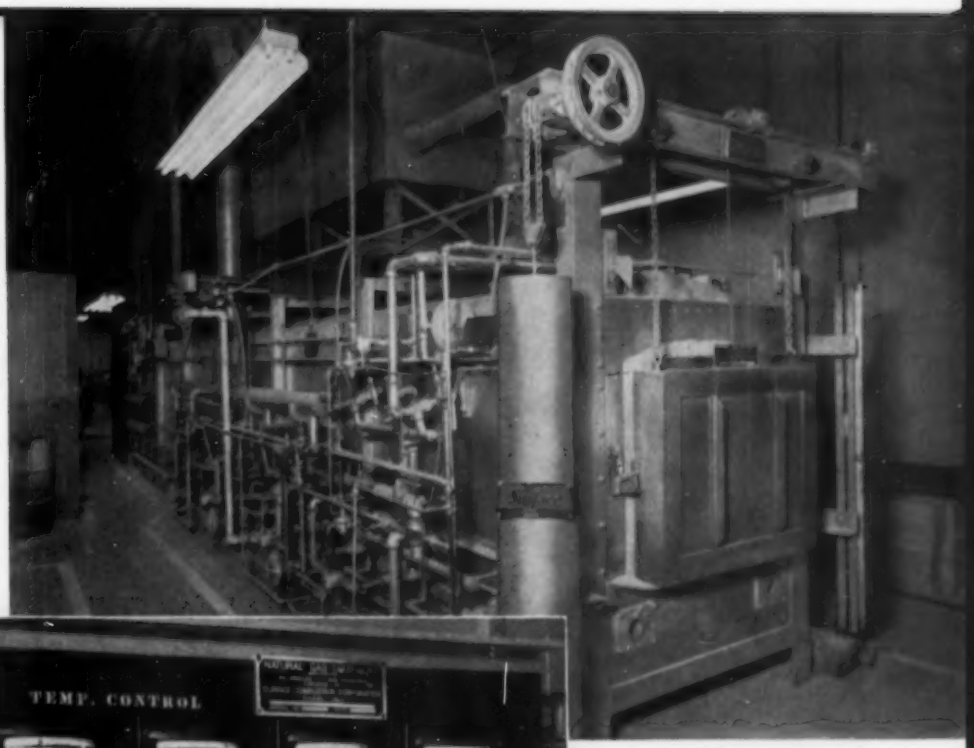

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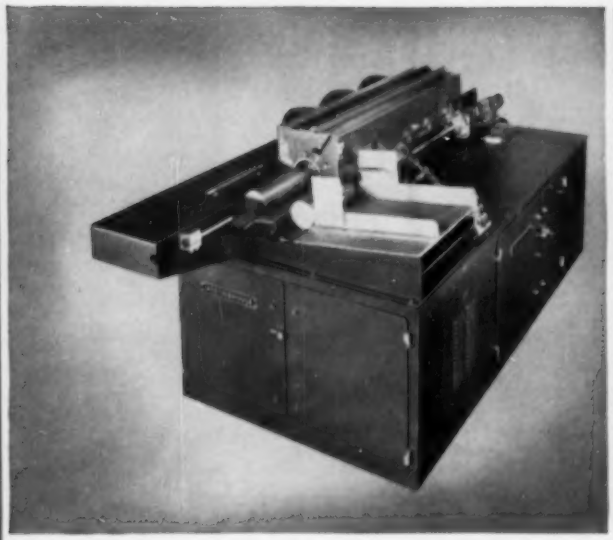
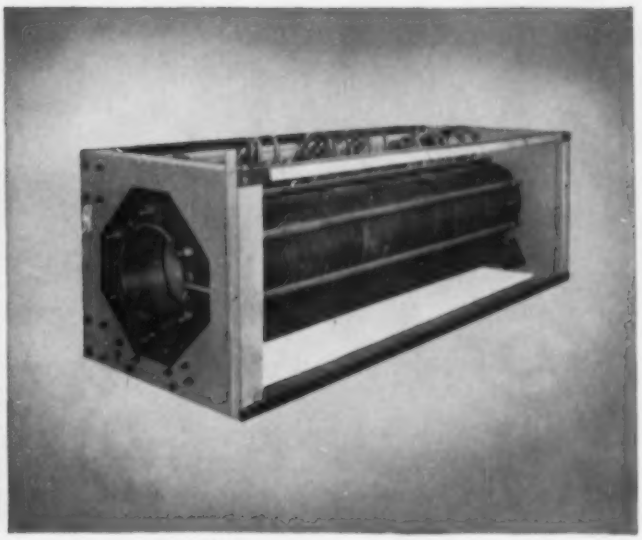


2. Heating 6- or 8-inch billets to 1,000°F, this Westinghouse induction unit delivers up to 5,000 lbs of billets an hour.



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These parts are done to a turn . . . in nice time, at low cost.

That's because the salt bath is contained in a Rolock "Neu-pot" made of wrought Inconel* nickel-chromium alloy.

KLK Manufacturing Company reported that unlike most "pot" materials, Inconel alloy retains original heat transfer characteristics throughout its useful service life. With it, loads can be hurried along as rapidly as good practice permits. Volume goes up, cost per piece down.

Long pot life lowers cost, too

In this installation, KLK goes on to say, Inconel nickel-chromium alloy also substantially increases pot life. They report that former pots gave, at best, only six weeks service. Their first Inconel "Neu-pot" lasted almost 5 times longer.

In overall pot expense KLK saves 50 percent by using wrought Inconel alloy. The company also realizes a major reduction in down-time. Both savings are reflected in the cost per piece.

Is high sustained heat, or heat plus severe corrosive conditions your problem? If so, look into Inconel. Write for the Inco booklet, "Keep Operating Costs Down As Temperatures Go Up."

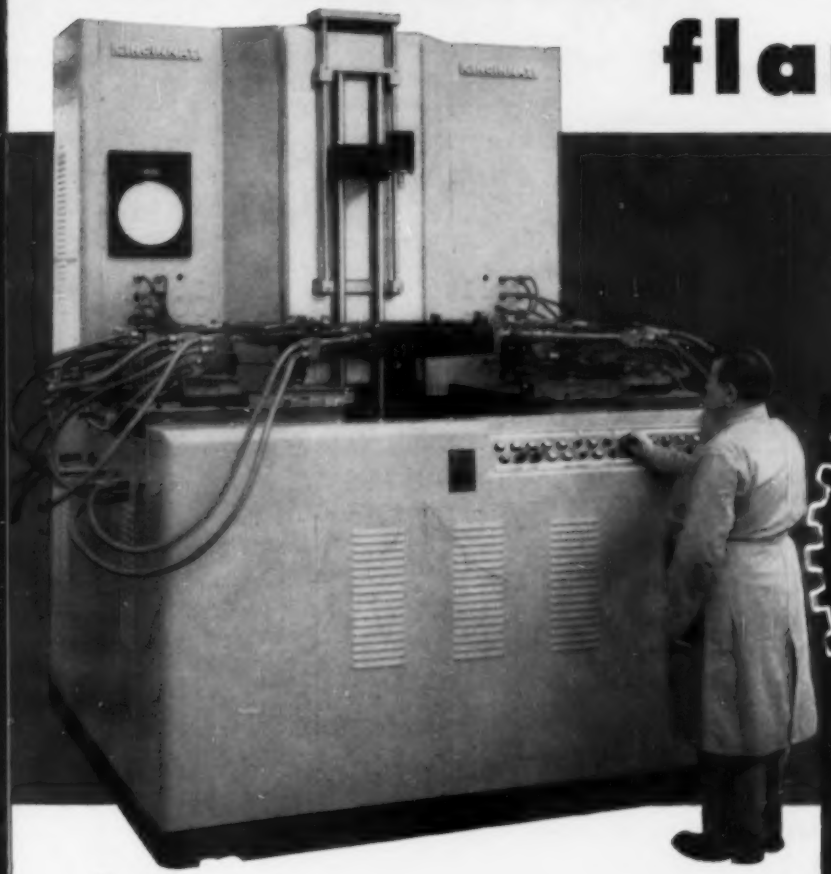
*Registered Trademark

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

Inconel... *for long life at high temperatures*

look at the part size range handled by this

NEWEST flamatic!



SELECTIVE SURFACE HARDENING CAPACITY:
diameters: 1½ to 32 in.
shaft lengths: to 4 ft.

This newest Cincinnati ® Flamatic hardening machine has the widest work range yet! It will spin harden circular parts ranging in size from 1½ to 32 inches in diameter, as well as progressive harden, spin harden or combination spin-progressive harden shafts up to 4 feet in length. Simple tooling on adjustable flame head holders provides easy changeover from job to job.

Feed rate for progressive hardening, where the work is fed vertically past the flame heads, is infinitely variable from 2 to 40 ipm. A rapid traverse rate from 20 to 400 ipm is also provided. This makes it possible to move the part rapidly from one heating zone to another when only specific areas of the part are to be hardened.

The machine, designed for pit mounting, will operate efficiently on acetylene, propane or natural gas. The quench tank, located beneath the heating station, has provisions for quench agitation.

Why not take *your* selective surface hardening problems to Cincinnati . . . *builders of both Flamatic® (flame) and Inductron® (induction) hardening machines.* Call in a Process Machinery Division field engineer. He is ideally equipped to evaluate your needs and give you unbiased recommendations as to the most economical equipment for your work.

CINCINNATI

flamatic and inductron

hardening machines

THE PROCESS MACHINERY DIVISION
THE CINCINNATI MILLING MACHINE CO.
CINCINNATI 9, OHIO, U. S. A.

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SINK DIES FASTER in FINKL Die Blocks with

Machining time, such as planing, rough cutting, milling, hand benching and burring are appreciably reduced on Finkl SMQ Die Blocks. Thorough field testing shows that the Special Machining characteristic of SMQ saves shop time and gets the die into production sooner.

There is a Finkl steel available for any forging need. All are quality controlled through each step from our own melt shop to final inspection.

When you next consider die blocks, your local Finkl representative will gladly help you plan for "impressions that last."

DIE BLOCKS
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HOT WORK STEELS
•
FORGINGS
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ELECTRIC FURNACE STEELS

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A. Finkl & Sons Co.
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HOW USS "T-1" STEEL IMPROVES THESE PRODUCTS:

Pays Off In Payloader. Speed is emphasized in International Harvester's new Model 12 Payloader. That means weight had to be cut. And USS "T-1" Steel helped cut weight of the rugged boom. This remarkably tough, strong steel is used at top and bottom sides where maximum stresses are imposed. The section depth of the USS "T-1" Steel parts is 12 inches. With other, less strong steels, section depths of 19 and 24 inches would have been required—much too large to fit the contour of the machine. USS "T-1" Steel cut size, weight . . . was cold bent, and welded to other parts of the machine by automatic submerged arc welding.

Stops Brake Breakage. Columbiana Cylinder Grinding Company, Columbiana, Ohio, does a lot of custom machining on industrial and mining equipment, including repair of brake and clutch bands for large earthmoving equipment. On the original equipment these bands are made of plain mild steel . . . often break under the tremendous stresses encountered. Columbiana replaces these broken bands with new ones of USS "T-1" Steel—has yet to have a USS "T-1" band break.

More Strength, Less Weight. This lift truck, in use at Baltimore Concrete Plank Corporation, and manufactured by Gerlinger Carrier Company, Dallas, Oregon, is the largest standard-line lift truck on pneumatic tires in the world. USS "T-1" Steel reduced the width and thickness of the forks on this truck. In addition, this extremely tough constructional alloy steel eliminated the need for shipping the forks 75 miles for heat treatment, which was required with the alloy steel previously used.

HOW IT CAN HELP YOU

USS "T-1" Steel, with its high minimum yield strength of 90,000 psi and its minimum tensile strength of 105,000 psi, can help you design or build lighter-weight equipment that will last longer. Its unusual toughness can help you design or build equipment capable of taking severe impact and abuse at sub-zero temperatures. Its excellent weldability can help you cut the cost of fabricating highly stressed parts, and reduce repair and maintenance expense. Its good creep rupture strength can help you put more durability in equipment that operates at temperatures as high as 900 degrees F.

Somewhere in your operation, versatile USS "T-1" Steel can help you. For technical assistance or information, write, wire, or phone United States Steel, Pittsburgh 30, Pa.

UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST • UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

SEE The United States Steel Hour; it's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

USS

UNITED STATES STEEL

"We forged 10-foot rings from a 5-foot ingot... in stainless steel"

says **John Matthews,**
U. S. Steel General Foreman—Forging

It required many days to take the photographs on this page, days of forging and re-heating. The forgings are made from type 304 stainless steel, and they're destined for a nuclear power plant. Now read why it took so long to make them.

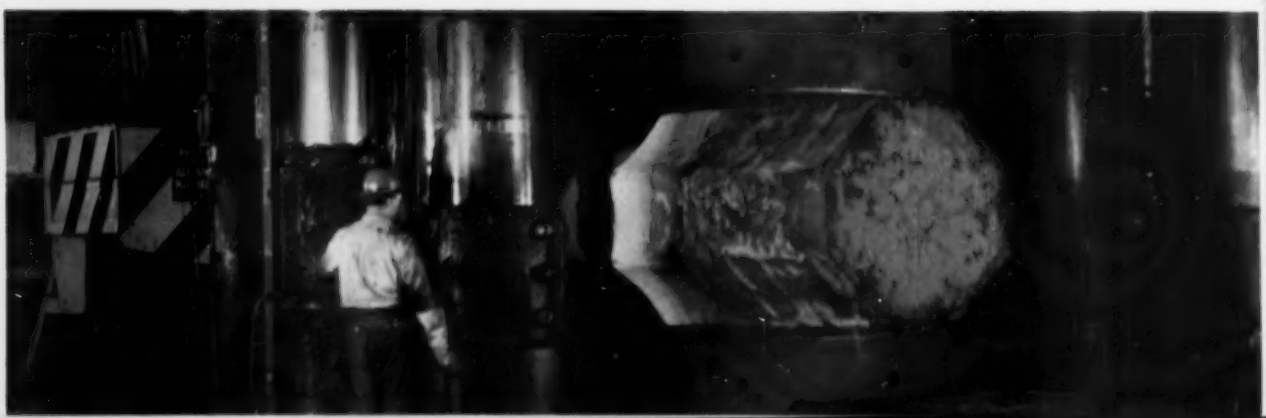
Stainless is strong and stiff, even at forging temperatures. It requires more passes through the press, more die pressure, and the dies wear out faster. If you forge it too long, so that it gets "cold," it will develop small surface cracks beneath the great jaws of the press.

In John Matthews' words:

"We started with a 59″ fluted ingot and forged it down to a 40″ octagon, then sliced it into three flat discs. The thickest disc was forged down to 18″, and we put a 23″ hole through it with steel punches. Then it was worked over the big steel mandrel to finished size: 119″ outside diameter, 80″ inside diameter, 10½″ thick. The other two rings were somewhat thinner."

It was a tricky job, but USS Quality Forgings like this are being turned out every day because we've got the men with the skill to do the job right.

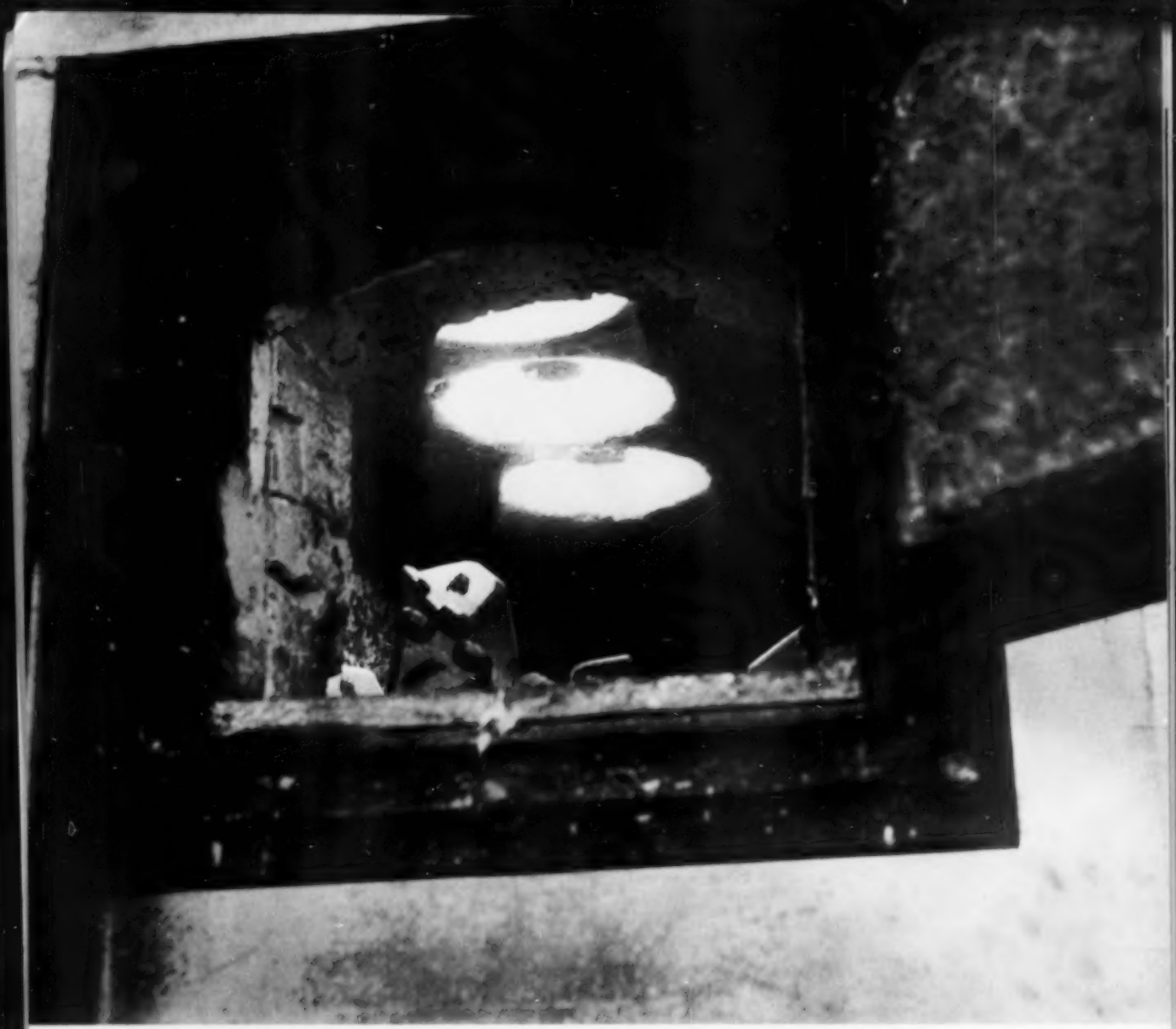
We'll certainly appreciate your inquiries. Send them, or requests for our free 32-page booklet on USS Quality Forgings to: United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.



USS QUALITY FORGINGS

heavy machinery parts . . . carbon, alloy, stainless
forged steel rolls and back-up roll sleeves
electrical and water wheel shafts
specialty forgings of all types

UNITED STATES STEEL



Roof arch of aluminum-melting furnace being fired up at Doehler-Jarvis Division of National Lead Company, Pottstown, Pennsylvania. Laclede-Christy "Steel Cast," a castable refractory containing Lumnite cement, replaced brick arch roofs in 31 furnaces. Refractory-concrete roof arches reported in excellent condition after two years of service.

Furnace Refractories give top performance with **Lumnite*** Concrete.

In job after job, where extreme temperatures and thermal shock are encountered, experience has shown that Refractory concrete made with Lumnite cement will give excellent service in aluminum-melting furnaces, also in other furnaces of many types, large and small.

Refractory concrete can be easily placed, using your own plant work force. Service strength is reached within 24 hours. A convenient way to make Refractory concrete is with castables. These are packaged mixes of Lumnite calcium-aluminate cement and selected aggregates designed for your specific job. They are prepared and distributed by leading manufacturers of refractories.

UNIVERSAL ATLAS CEMENT COMPANY

UNITED STATES STEEL CORPORATION SUBSIDIARY

100 PARK AVENUE, NEW YORK 17, N. Y.

* "LUMNITE" is the registered trade-mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

L-195

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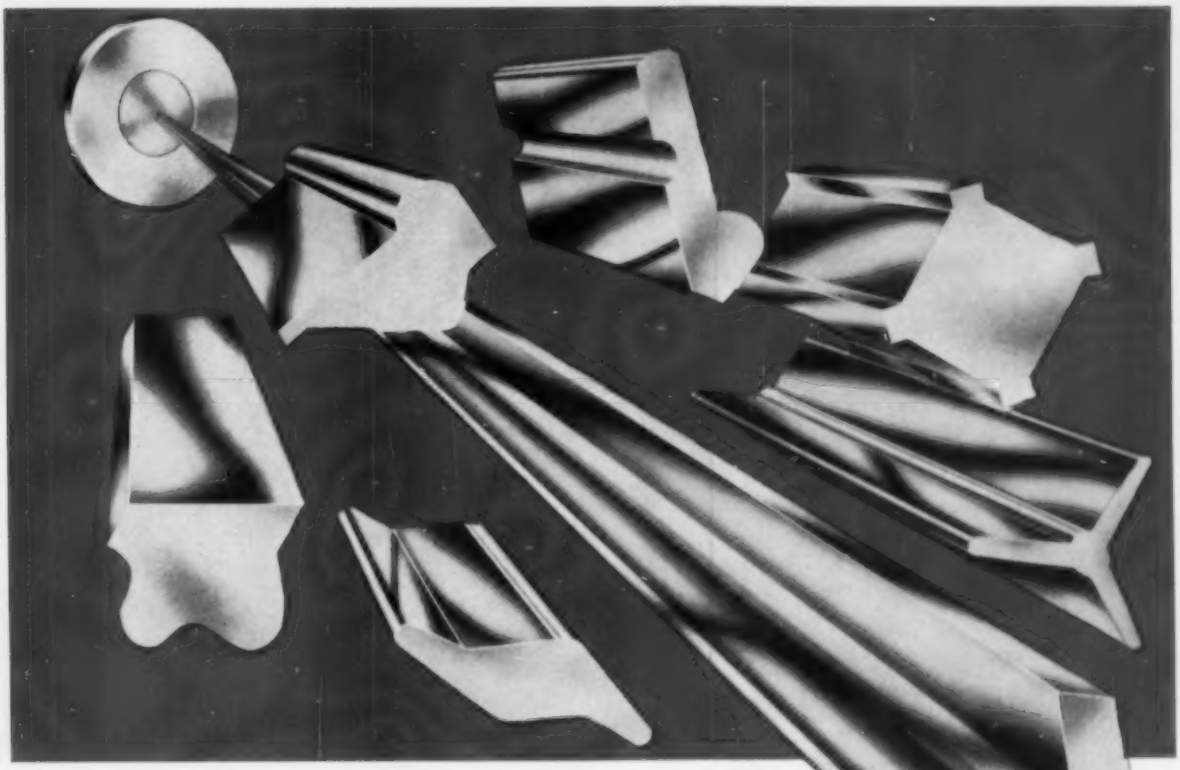

J&L custom-made hot extruded cold drawn sections... boost production, cut over-all costs

Progressive industry is today utilizing J&L's Custom-Made, Hot Extruded Cold Drawn Steel Sections to:

1. **Eliminate time and costs** in machining and finishing operations
2. **Reduce scrap losses** practically to the zero point
3. **Eliminate the cost of castings and forgings** of intricate sections requiring considerable machining
4. **Reduce inventories** due to quick availability of extruded sections from the J&L plant

These sections can be extruded and cold drawn to the exact specifications of the parts you require — in any quantity you specify. Even the production of a single extrusion can be economical. Obtainable in a wide range of material grades, J&L Extruded Sections can be produced in a large variety of shape profiles — within limits of a design which can be inscribed within a two-inch circle. Many shapes that cannot be hot rolled are practical for the extrusion process.

The mechanical properties of J&L Extruded Sections are equal to or superior to those obtainable from equivalent grades conventionally cold drawn. Cold drawn tolerances are accurately maintained. The excellent surfaces of these Extruded Sections require little — if any — finishing operations.

Send us your inquiry for prompt and efficient J&L service.

J&L STEEL

Write today for your copy of this free new booklet which gives detailed information about the many money- and time-saving advantages J&L Extruded Sections offer you.

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Please send me your new Booklet on *Extruded Sections*

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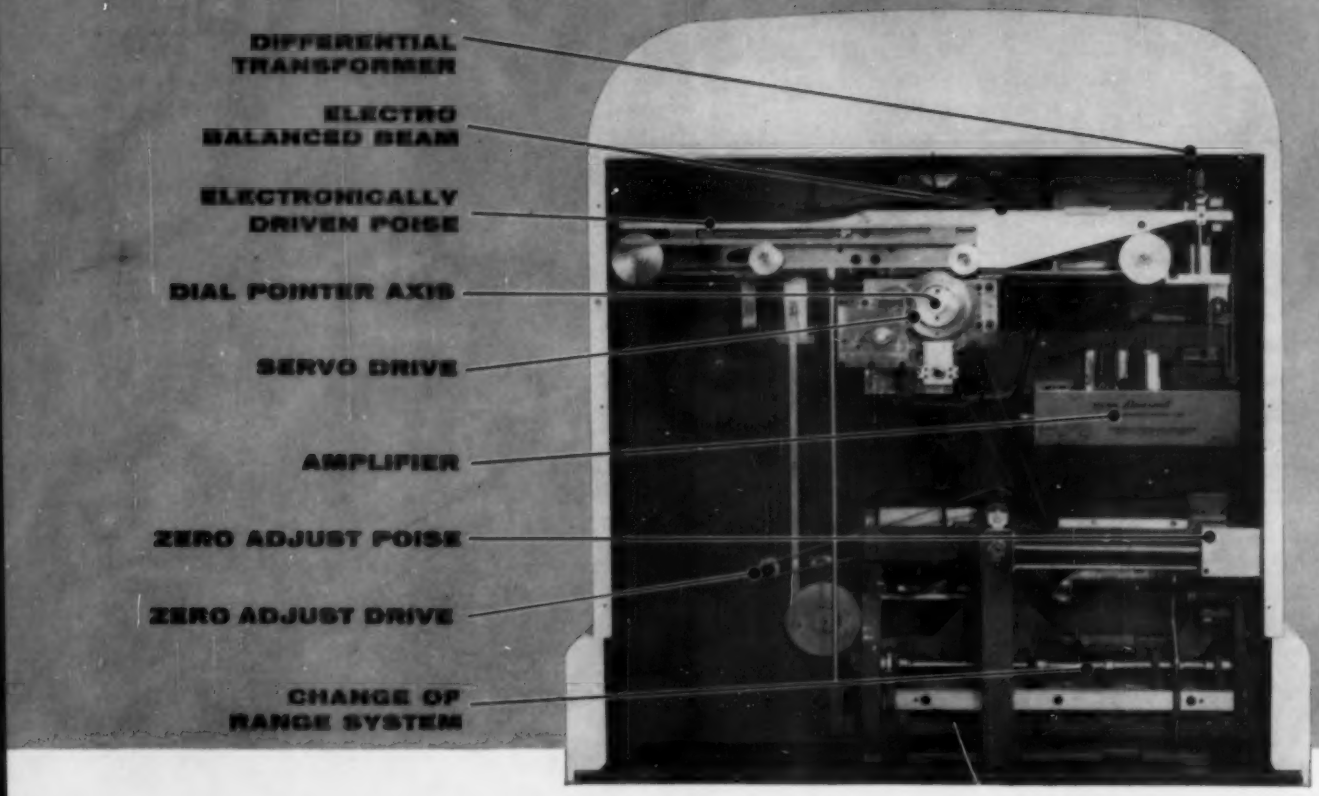

Riehle's rapid-response and sensitive weighing system. Slight motion at beam end provides sufficient signal to operate the servo motor and move the poise to establish force equilibrium.

new sensitivity...rapid response

ON THIS LATEST RIEHLE INDICATING UNIT

If the tests you make today require greater sensitivity and more rapid response than those of yesterday, you can be sure that your tests of the near future will have still more stringent requirements. This new Riehle Electro-Balanced Indicating Unit is for you. With its greater flexibility and precision, it anticipates *tomorrow's* requirements of research practices . . . of development practices . . . of control practices. Available for both hydraulic and screw power testing machines — by Riehle. Complete line of Riehle-built accessories.

NEW 4-PAGE BULLETIN . . . JUST MAIL COUPON

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Division of American Machine and Metals, Inc.
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Please send your free 4-page Bulletin RU-14-56 with full data on the new Riehle Electro-Balanced Indicating Unit.

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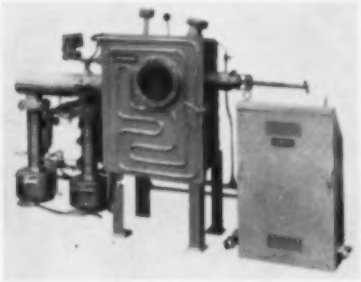
ATTENTION MR.

APPLICATION and EQUIPMENT new products

Vacuum Furnace

A new vacuum furnace for precision casting operations has been announced by F. J. Stokes Corp. The new unit is capable of melting and pouring single casts of 5 to 17 lb. under



vacuums as low as 2 microns. Production cycles as short as 10 to 12 min. are possible when vacuum melted metal is used for the feed stock. Cycles will be somewhat longer when air-melted stock is used which has to be degassed and further purified under vacuum.

For further information circle No. 1580 on literature request card, page 48-B.

Spectrochemical Standards

Spex Industries, Inc., has announced a set of eight low-alloy steels of the British Bureau of Analysed Samples prepared for X-ray spectrochemical analysis. The standards are mounted in discs 1 in. in diameter by ⅝ in. thick. Containing certified concentrations of eleven elements in graded steps, the standards are valuable for the determination of 0.2 to 3.1% Cr, 0.05 to 5.1% Ni, 0.17 to 1.5% Mn, 0.12 to 0.67% V, 0.19 to 1.4% Mo and 0.1 to 0.46% Cu.

For further information circle No. 1581 on literature request card, page 48-B.

Brazing Alloys

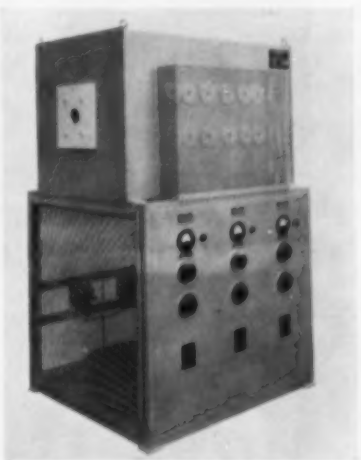
Handy & Harman has announced a series of four high-nickel brazing alloys for brazing austenitic stainless steel, high-nickel heat-resistant and precipitation-hardening alloys. They will also braze carbon steel and nonferrous metals having melting points above 1850° F. The four high-nickel alloys have nickel contents ranging from 72.50 to 93.25%, silicon between 3.50 and 5.00% and boron between 1.90 and 3.50%. The alloys are self-fluxing when used in a controlled atmosphere of dry hydrogen, argon or helium. Properly designed joints will have tensile strength of 75,000 to 95,000 psi. depending on the atmosphere used, joint clearance and the composition of the brazing alloy. The four high-nickel alloys have flow points in the range of 1825 and 1925° F. All the alloys are available as cast rod, powder, resin-bonded sheet, as well as in forms fabricated and sintered from powder.

For further information circle No. 1582 on literature request card, page 48-B.

Heat Treating

Hevi-Duty Electric Co. has announced a new high-temperature tube furnace, large enough for production work, as well as laboratory analysis. Working temperatures range from 1700 to 2600° F. The working chamber is 27 in. long and will accommodate tubes up to 5 in. o.d., while the overall length of the furnace is 42 in. Silicon carbide heating elements are arranged perpendicular to the tube, above and below the chamber.

For further information circle No. 1583 on literature request card, page 48-B.



Rhodium Plate

A new rhodium plating process, which produces compressively stressed deposits, eliminates curling, cracking and peeling, has been announced by Sel-Rex Precious Metals, Inc. A test employed to evaluate the new process called for dissolving the basis metal from an object plated with rhodium. With a sample plated by the conventional process, the rhodium disinte-

grated into small crystalline flakes, the edges curling away from the basis metal, demonstrating its inherent high tensile stress. When an object plated with Rhodex-CS was subjected to the same test, a continuous electroplated film remained, the edges curling toward the basis metal, indicating that the deposit was under compressive stress.

For further information circle No. 1584 on literature request card, page 48-B.

pH Recorder

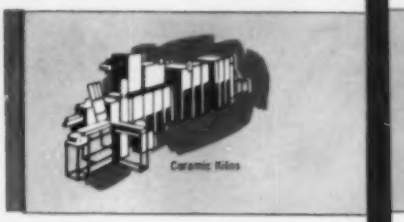
Portable, self-contained, pH measuring and recording instruments requiring no external power supply have been announced by Bristol Co. The new device consists of two units: a Model 524 pH recorder and a Beckman N-2 amplifier. This equipment will cover the total pH range of 0 to 14 in two partial ranges of 0 to 8 and 6 to 14. The two units together weigh less than 50 lb.

For further information circle No. 1585 on literature request card, page 48-B.

Pipe Straightener

A major improvement in the design of the heavy-duty rotary tube straightener that makes larger models of the

BRAND-NEW IDEA in heat treating furnaces



proving again . . . .

FOR CARBONITRIDING, BRIGHT HARDENING, CARBURIZING OF SMALL METAL PARTS

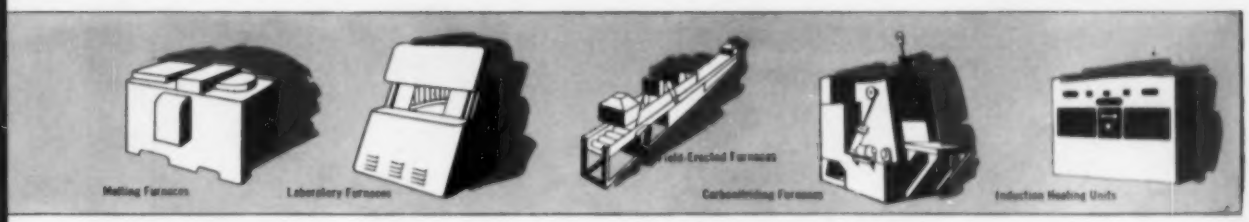
This is a completely new furnace, an exclusive Lindberg development. It is the first time induction heating has ever been offered in a heat treating furnace. No elements, no burners, no electrical or gas connections in it. Heating efficiency is high and the furnace can be brought to hardening temperatures in 17 minutes from cold. Temperature control is highly accurate, eliminating temperature override and lag for all practical purposes.

The Induct-O-Ring's circular shape eliminates door-opening heat and atmosphere losses and saves floor space. Work load is automatically charged and moved through the work chamber by a gentle, quiet, reciprocating movement of the furnace. The furnace is completely adaptable to automatic production processes, where its precise heat control, negligible maintenance and dependable operation are of particular importance.

- No elements, no burners
- No gas or electric connections in furnace
- Built like a fine machine tool
- Precise temperature control
- Very low maintenance
- Quiet, automatic, trouble-free

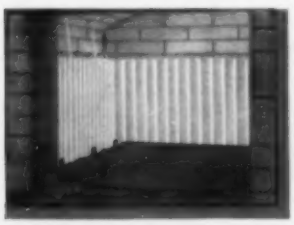
induct-O-ring*

*U.S. and foreign patents pending



. . . it's better to talk it over with LINDBERG

If you are concerned with the application of heat to industry it makes good sense to talk it over with the most widely experienced experts you can find. We believe we have them here at Lindberg. Our only job is developing industrial heating equipment and we offer the most complete line in the field; heat treating furnaces, melting furnaces, high-frequency induction units, ceramic kilns; big ones, small ones, built in our own plant or field-erected. This gives us the experience and know-how to come up with something really new, like this revolutionary Induct-O-Ring furnace, time and time again. So take your industrial heating problems to the experts. Our engineers and technicians can have the right answer. Talk it over with Lindberg.



Another Lindberg achievement! The use of electricity in carbonitriding and carburizing furnaces has been made completely practical by Lindberg's recent development of the CORRTHERM electric heating element. This element is now being used in many furnace installations where ordinary electric heating elements could not operate successfully.

For fuel-fired furnaces, another important development, the famous "dimple" vertical radiant tube was created by Lindberg. This lightweight, easily-changed tube provides a big advance in furnace efficiency and effects a marked saving in operation and maintenance costs. Minimizes shut-downs and costs for tube changes.

Through the years Lindberg research and development laboratories have originated and perfected many other important heating processes, developments such as the Cyclone tempering furnace, automatic control of carbon potential in furnace atmospheres, 60 cycle induction melting and completely automatic ceramic kilns.

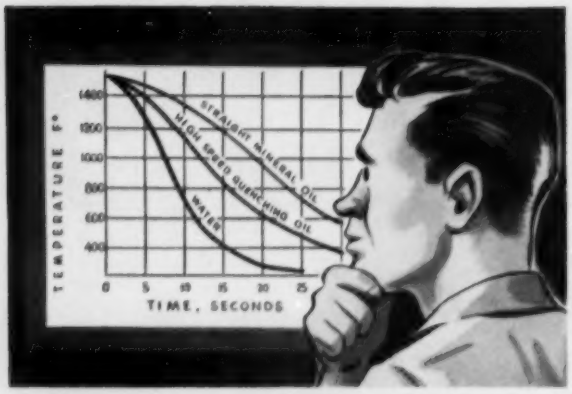
Many important Lindberg developments have come as a direct result of some good customer's need. With the customer's cooperation Lindberg engineers have frequently provided an answer to some pressing production problem. You will benefit, too, whether you need some specific Lindberg equipment or have an industrial heating problem that needs a solution if you'll just talk it over with Lindberg. Call your nearest Lindberg Field Representative. There's one (see your phone book) in every major industrial center.

LINDBERG ENGINEERING COMPANY

2448 West Hubbard Street, Chicago 12, Illinois

Los Angeles Plant: 11937 S. Regentview Ave., at Downey, Calif.

Associate Companies: Lindberg Industrial Corporation, Chicago • EFCO-Lindberg, Ltd., Montreal, Canada • Lindberg Italiana, Milan, Italy • The Electric Furnace Company, Ltd., Weybridge, Surrey, England • Etablissements Jean Aubé, Paris, France • Lindberg Industrie Ofenbau, Gross Auheim, Germany • Toyo Menka, Tokyo • Lindberg Engineering Company (Australia) Pty. Ltd., Melbourne



1. Quenching Speed. There are two basic types of quenching oils...straight mineral oils and compounded high-speed oils. If you can get the microstructure and hardness you need and have no distortion problems with a straight mineral oil, then it's the type to use. If you're not getting the results you want, increased agitation may help. If increased agitation doesn't help, or isn't practical, you should use a high-speed oil.

2. Naphthenic vs. Paraffinic. Both types of oil are used for quenching. Both have their own inherent advantages. Naphthenic oils keep oil coolers cleaner when the temperature of the oil doesn't exceed 150 F. A fully dewaxed paraffinic oil gives the most satisfactory results at temperatures over 150 F. As a rule, when all other operating factors are equal, the temperature of your oil bath tells you which type of oil to use.

What's the difference in quenching oils?

3. Thermal Stability. This is the biggest single factor influencing the useful life of a quenching oil. The higher the temperature of the oil bath, the shorter the life of any given oil. As mentioned before, at temperatures over 150 F it takes a stable, fully dewaxed paraffinic oil to give the most satisfactory results. For maximum useful life at temperatures over 200 F you will probably need a specially inhibited quenching oil.

4. Other Considerations. When quenching from a salt pot, use a straight mineral oil. Don't use an oil containing lard oil or other vegetable or animal fats. The salt carried into the oil on the parts will cause these fats to saponify and form oil-thickening grease. For bright quenching, experience shows that a straight mineral oil will give the best over-all results. For the most part, a straight oil will give cleaner parts longer.

These facts are nothing more than a guide to help you select the quenching oil best suited to your particular needs. To arrive at the final answer, there's no substitute for experience. Sun's representatives, backed up by Sun's metallurgical staff, have that experience. And, they're backed up by a *complete* line of quenching oils, paraffinic or naphthenic, regular or high-speed, straight or inhibited. Sun makes them all. For more information, see your Sun representative or write SUN OIL COMPANY, Philadelphia 3, Pa., Dpt. MP-12.

INDUSTRIAL PRODUCTS DEPARTMENT

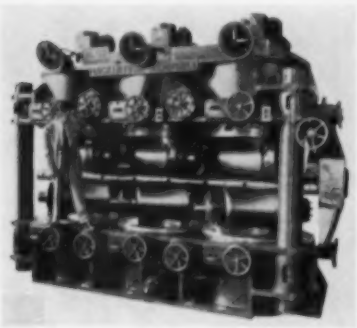
SUN OIL COMPANY

PHILADELPHIA 3, PA. ©SUN OIL CO.

IN CANADA: SUN OIL COMPANY LIMITED, TORONTO and MONTREAL

SUNOCO

machine easier to adjust and maintain under adverse operating conditions has been announced by the Mackintosh-Hemphill Div. of E. W. Bliss Co. The new design is an adaptation of a rigid three-post arrangement of supports between the bed and the top of the machine. Specific advantages of the new construction are that it eliminates possibility of interference between the support posts and the six roll-drive spindles, and that it offers



better front access to the roll group. It also makes possible quick roll changing and faster and more certain roll adjustment and roll locking. The model A-5 illustrated will be used to straighten electric-welded steel pipe in lengths from 16 to 65 ft. and diameters of 4½ to 16 in. It will operate at speeds of 60 to 240 ft. per min.

For further information circle No. 1586 on literature request card, page 48-B.

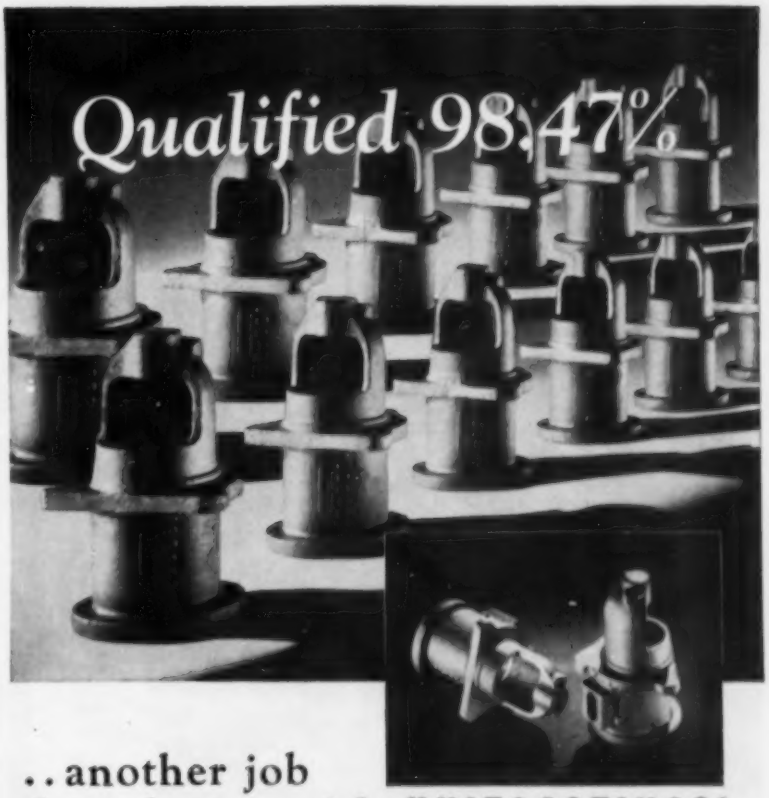
Heat Treating Furnaces

Lindberg Engineering Co. has announced a special new line of furnaces specifically designed for pilot plant operations. The new line includes six units: an atmosphere box furnace 6 by 12 by 5 in. for continuous operation at 2600° F.; a box furnace 5½ by 7½ by 14¼ in. with reactor control; a 3 k.w. high frequency induction furnace; a horizontal tube furnace; a vertical tube furnace 5 in. o.d. by 8 in.; a high temperature pot furnace for operation to 2500° F.

For further information circle No. 1587 on literature request card, page 48-B.

Thermocouple Connections

A new line of plug-in thermocouple components, designed to simplify and speed-up connection of thermocouples to industrial instruments, has been announced by Minneapolis-Honeywell Co. The connecting units consist of a series of plugs, jacks, multiple jack panels, cable clamps and tube connectors, and can be used for either single of multiple thermocouple connections. One contact is always slightly larger than the other to prevent improperly polarized connections.



..another job
done better with ***UNITCASTINGS!***

Faced with a problem of economically producing a starter housing that would take more than normal abuse, Unitcast engineers successfully provided the answer with *steel* castings. Previous to the use of Unitcastings, replacement costs were excessive and the need of a tougher material was imperative. Cost was also an important requisite, and by delivering *consistent* quality in conjunction with a tougher material—scrap and lost time has been held at a minimum. To date, more than 33,000 units have qualified with a higher basic cost being offset by practically no replacement and most important —a lower *finished* cost!

Take another look at the *finished* cost of your parts inventory —perhaps you *can do better with Unitcastings!* Consult a Unitcast engineer, soon!

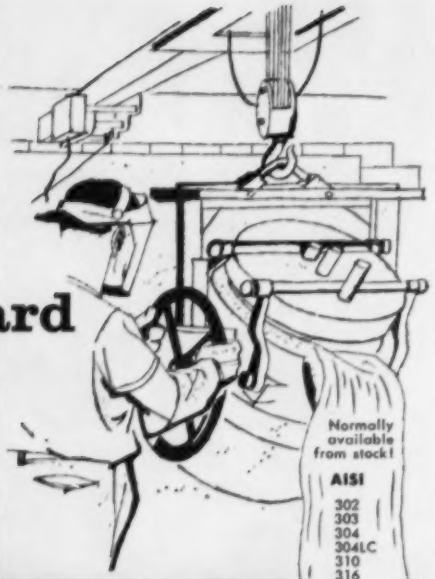
UNITCAST CORPORATION, Toledo 9, Ohio

In Canada: CANADIAN-UNITCAST STEEL, LTD., Sherbrooke, Quebec

Unitcast

QUALITY STEEL CASTINGS

Call Cannon-Muskegon for standard and custom alloys



...in pounds or tons

for quality casting, rolling or forging applications

Normally available from stock!

AISI
302
303
304
304LC
310
316
330
347
410
416
420
431
440A
440C
440F

ARMCO 17-4-PH
INVAR
M-252
WASPALLOY
X-40

AMS
5334
5350
5354
5358
5360
5362
5366
5370
5373
5376
5382
5385
5610
5628
5630
5631
5640

SAE
"H" B-2
"H" D-2
M-2
T-1
1010
4130
4145
*4620
52100
6150
8620

PWA651
PWA787M
*NI-RESIST 1A
*INCONEL
*MONEL
4750
WAD 8338
WAD 8370

Cannon-Muskegon can provide the alloy you need in whatever amount you want . . . with exactly predictable control of characteristics. Check the alloys we produce for industry's special needs . . . one or several can solve your problem. If not, Cannon-Muskegon can help you select and produce the right material . . . recommend proper handling methods for best results. You can be sure of getting the desired physical, chemical and electrical properties for your particular machining or processing operation. And remember — Cannon-Muskegon *certifies* specifications of its MasterMet alloys.

Test or production lots available

We are equipped to supply you with sample or production quantities. There's a wide choice of carbon and 300 and 400 series stainless steels available from stock for immediate delivery. Preparation of special alloys begins immediately on receipt of your order. Alloys are available in shot, ingot, billet or cast bars.

Now... UltraMet vacuum melted alloys

Cannon-Muskegon announces vacuum melting facilities for the production of iron-, nickel- and cobalt-base alloys up to temperatures of 3100°F . . . and special alloys for industry . . . in ingots or cast billets. We are ready to provide cleaner, stronger and more ductile alloys for remelt . . . sample development and production of vacuum process castings . . . and cast ingots for forging, extruding or machining.

Write for your copy of New MasterMet Bulletin and technical data on the complete MasterMet alloy service.

MASTERMET
CERTIFIED ALLOYS FOR INDUSTRY

CANNON-MUSKEGON CORPORATION
2879 Lincoln Street Muskegon, Michigan

*®International Nickel Co.

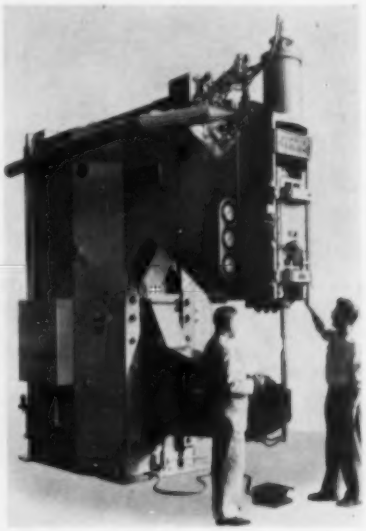
METALLURGICAL SPECIALISTS

Each connector component has the thermocouple type etched on a disk on its body for quick identification.

For further information circle No. 1588 on literature request card, page 48-B.

Spot Welder

The Federal Machine and Welder Co. has announced a three-phase frequency converter spot welder 13½ ft. high and weighing over 58,000 lb. It is designed with a special throat



or work clearance area of approximately 2100 sq. in. A three-phase unipolar transformer supplies 100,000 amp. of welding current and weighs over 25,000 lb.

For further information circle No. 1589 on literature request card, page 48-B.

Blanking Stainless

Sesco, Inc., has announced a new pressroom unit which will handle stainless steel, aluminum, brass and highly polished stock without danger

of scuffing. First, a stock lubricator unit submerges the stock, lubricates it completely, and then removes the excess lubricant. Next, a scuff-free hydraulic double gripper feed moves stock to within 0.003 in. of the selected setting. A third feature is a precision

cut-off which is sequenced with the feed cycle.

For further information circle No. 1590 on literature request card, page 48-B.

Heat Treating

A new type of heat treating furnace for carbonitriding, bright hardening and carburizing of small parts has been announced by Lindberg Engineering Co. The induction heating principle was used in this furnace eliminating any heating elements,

element terminals, burners, gas or electric connections in the furnace proper. The operation of the furnace is automatic. The circular furnace has a reciprocating motion. It turns slowly in the direction of work travel then quickly reverses. With each action the work remains in the forward position and regularly progresses through the chamber until it reaches a discharge chute.

For further information circle No. 1591 on literature request card, page 48-B.

Solder

A new activated rosin core solder has been announced by Federated Metals Div. The activating chemicals used are not toxic. The solder fluxes quickly and it pierces oxide film and corrosion products on the parts to be soldered in less time than conventional solders. It is available in 40-60 and 60-40 lead-tin combinations in common 0.062 in. diameter wire.

For further information circle No. 1592 on literature request card, page 48-B.

Surface Projector

A new portable contour and surface projector has been announced by the American Optical Co. It is suited for inspection and examination of relatively flat objects and small parts, imprinted circuits, fine print of small scale drawings and like applications. Two models are available: one enlarges the original material three

times and the other, five times. The counter-balanced optical head is lowered into contact and the magnified image is projected onto an illuminated 4½ x 12 in. viewing screen.

For further information circle No. 1593 on literature request card, page 48-B.

Thickness Measurement

A new ultrasonic thickness measuring instrument has been announced by Magnaflux Corp. The new S-100 Sonizon is portable, weighing only 30 lb. Circuits for complete automatic operation have been built in. These circuits are used to impose predetermined tolerance limits on the instrument so that it will automatically actuate "go-no go" equipment or alarms, depending upon the measurement. Di-

TITANIUM BAR

72012 LBS.

TI 140 A	Round	9"	4920 lbs.
TI 140 A	"	8"	14138 "
TI 140 A	"	7"	47536 "
TI 155 AX	RCS	7½"	1912 "
RC 130 B	"	9"	824 "
RC 130 B	Flat Stock	1⅝" x 10"	1611 "
RC 130 B	" "	1-9/16" x 10"	267 "
RC 130 B	Rounds	6½", 7", 7½"	804 "

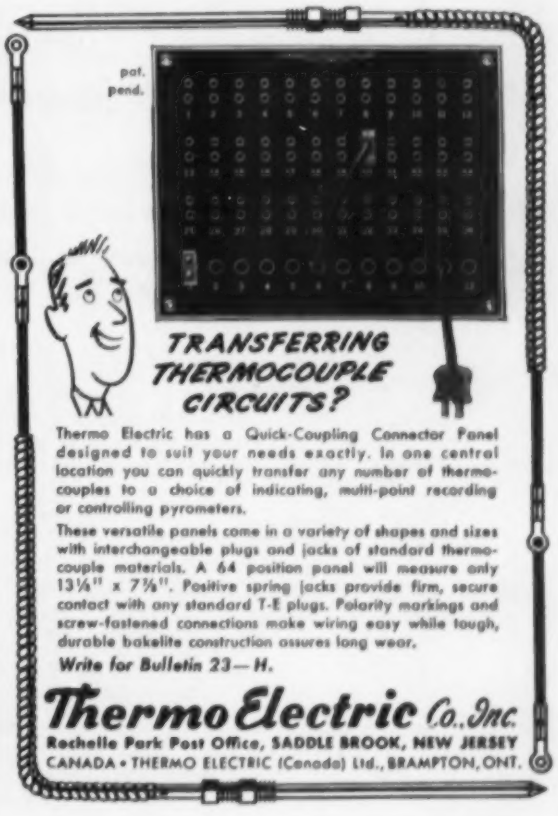
$3.75 per pound

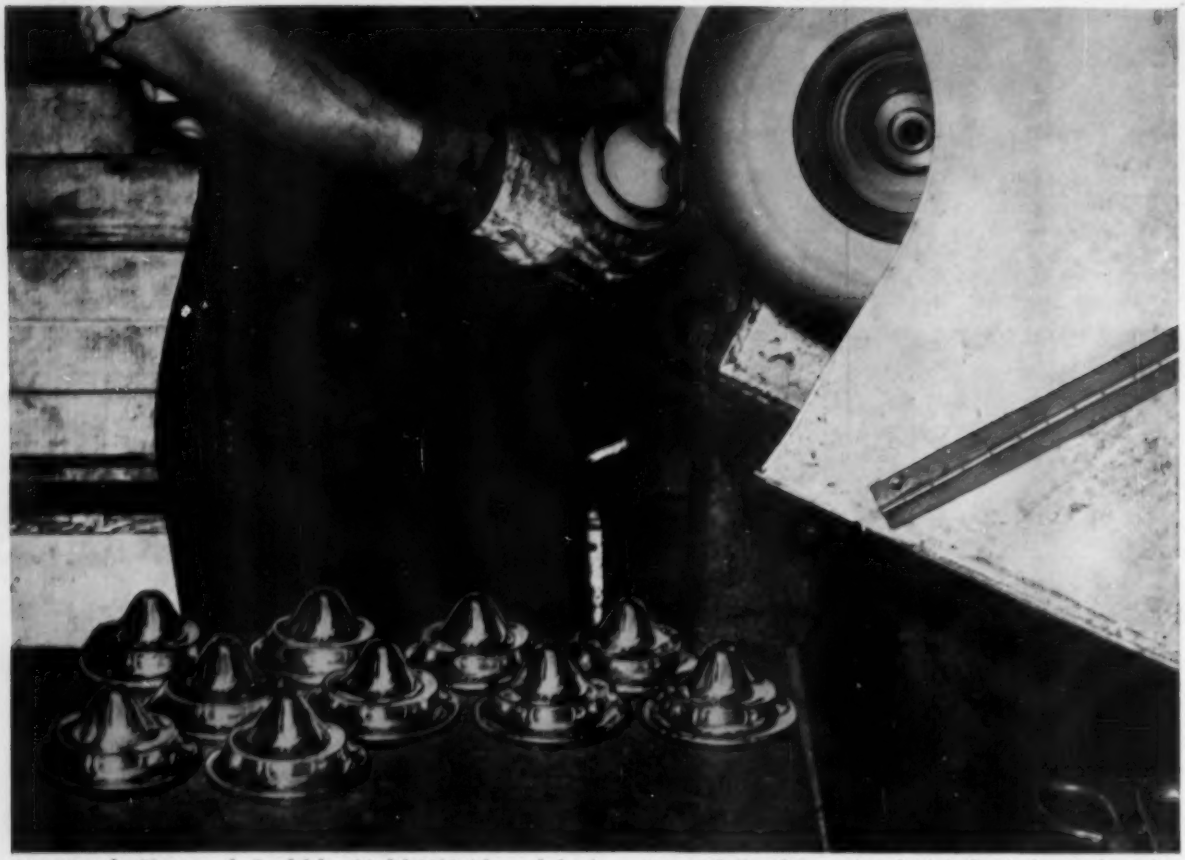
For 1000 lbs. or more

MILT GROBAN

9656 S. Merrion Ave. Chicago 17, Ill.

SAginaw 1-3442


pat. pend.
TRANSFERRING THERMOCOUPLE CIRCUITS?
Thermo Electric has a Quick-Coupling Connector Panel designed to suit your needs exactly. In one central location you can quickly transfer any number of thermocouples to a choice of indicating, multi-point recording or controlling pyrometers.
These versatile panels come in a variety of shapes and sizes with interchangeable plugs and jacks of standard thermocouple materials. A 64 position panel will measure only 13⅛" x 7⅛". Positive spring jacks provide firm, secure contact with any standard T-E plugs. Polarity markings and screw-fastened connections make wiring easy while tough, durable bakelite construction assures long wear.
Write for Bulletin 23—H.
Thermo Electric Co. Inc.
Rochelle Park Post Office, SADDLE BROOK, NEW JERSEY
CANADA • THERMO ELECTRIC (Canada) Ltd., BRAMPTON, ONT.



THE BASE of a Huntercraft Candelabra Model 8008 (shown below) requires, with Formbrite, only a finish buff. The base is formed in two drawing operations. The deeper drawn candle cups, also of Formbrite, need only a light cutting with Tripoli and a finish buff.

It's easy to get a jeweler's finish with Formbrite

HUNTERCRAFT Table or Wall Candelabra Model 8008, one of 30 fine brassware items in the line of Huntercraft Originals.

"Formbrite cut polishing cost and time dramatically—was a major factor in keeping our small business alive . . . and growing," says Ralph E. Hunter of Huntercraft.

THE production of Huntercraft Originals—now a nationally distributed line of fine brassware—has grown from a basement hobby to a thriving new business in less than 5 years.

The Hunter Machine Service Company of Racine, Wisc., began manufacturing Huntercraft Originals on a commercial scale in 1951, using ordinary soft forming brass. To get the gleaming jeweler's finish required, polishing time and costs were high. In fact, they were so high that the young company found it impossible to bring their prices into line with competition.

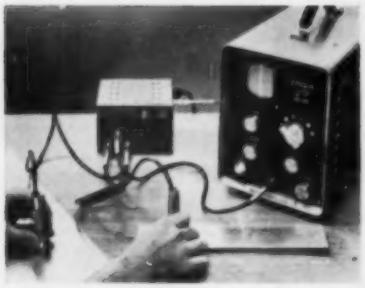
In 1953, they tried Formbrite®, Anaconda's superfine-grain drawing brass. The polishing bottleneck was broken and production soared – unit costs went way down. According to Ralph E. Hunter, owner and president of Hunter Machine Service Co., Formbrite was a major factor in keeping the company alive and enabling it to go on to become a stable, growing business. The finish obtained so easily on Formbrite, he adds, is superior to that achieved on ordinary drawing brass.

Formbrite is a premium product at a nonpremium price. Find out for yourself how its superfine-grain, excellent drawing properties, strength, and scratch-resistance can help you make a better product at lower cost. Write for Publication B-39. Better yet, ask for a sample or a trial batch. Address: The American Brass Co., Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 3672

Formbrite SUPERFINE-GRAIN DRAWING BRASS

an ANACONDA® product

made by The American Brass Company

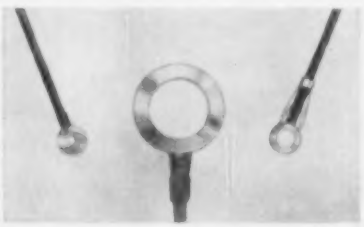


rect reading range is to 0.500 in. but measurement to 5 in. may be made with an accessory comparator.

For further information circle No. 1594 on literature request card, page 48-B.

Thermocouples

A new line of miniature gasket-type thermocouples has been announced by Thermo Electric Co. This new line includes a wider choice of gasket sizes, thermocouple leads and lead terminals. Industrial uses of gasket thermocouples include measuring skin



temperatures in chemical and food processing, metalworking, atomic energy and many others. These gasket thermocouples are available in three ranges: —300 to +600° F. with copper-constantan calibration and copper gasket; 75 to 900° F. with iron-constantan calibration and copper gasket; and 900 to 1200° F. with iron-constantan calibration and stainless steel gasket.

For further information circle No. 1595 on literature request card, page 48-B.

Spray Cleaners

Northwest Chemical Co. has announced a new series of high efficiency spray cleaners. They remove all types of production soil from zinc, copper, brass and steel. An unusual feature of the new cleaners is their low foaming action. Jet cleaners are nontoxic, harmless to racks and equipment, have no disposal problems and are dustless and noncaking.

For further information circle No. 1596 on literature request card, page 48-B.

Recorder Pens

Jewel-tipped pens have been incorporated into a line of strip chart recording instruments made by Minne-

YESTERDAY
TODAY
TOMORROW

CONTINENTAL

Serves Industry Everywhere

COMPLETE PLANTS designed, constructed, and equipped as an integrated unit for efficient and economical production.

CONTINENTAL

Tomorrow's Designs Today

SPECIAL EQUIPMENT industrial furnaces, ovens, gas generators, and dryers—all fuels—field or shop erected.

PRODUCTION LINES tailored to individual needs requiring minimum labor for maximum output.

CONTINENTAL

30 Years' Extensive Experience

insures prompt service in planning and production by experienced engineers who know industry's problems. Our numerous sales and service centers keep in constant touch throughout all phases of the work.

Write for Booklet No. 135

This booklet covers the scope of CONTINENTAL Service. It is well illustrated with views of CONTINENTAL installations with descriptions of the equipment and the processes performed.

5242

CONTINENTAL INDUSTRIAL ENGINEERS, INC.

176 W. Adams Street, Chicago 3, Illinois

DISTRICT REPRESENTATIVES

Ridgewood, N. J. • Indianapolis • St. Louis • Detroit
Cincinnati • Milwaukee • Cleveland • Pittsburgh

NH_3 Storage SYSTEMS

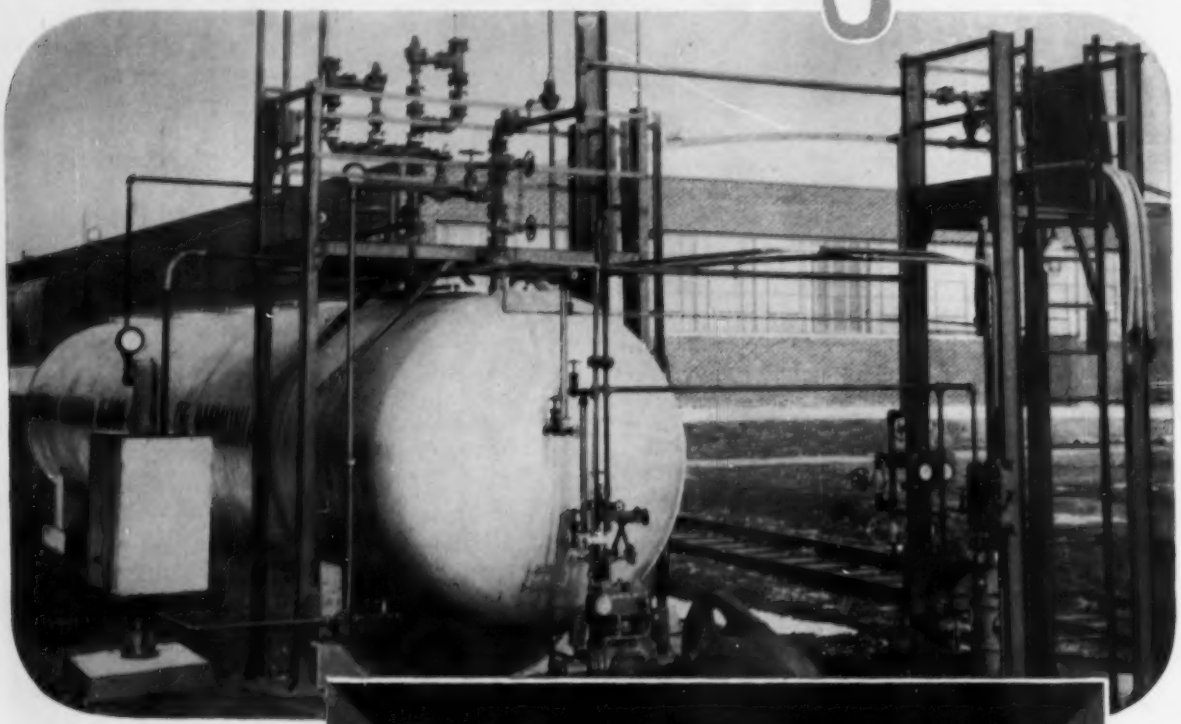


Illustration of typical outdoor installation of 15,000 Gallon Ammonia Storage System.

Drever Company offers years of experience in designing and installing unloading and storage facilities for handling anhydrous ammonia.

Systems tailored to meet individual plant requirements.

DREVER COMPANY

RED LION ROAD AND PHILMONT AVE. BETHAYRES, PA.

28

apolis-Honeywell's Industrial Division. Minute, clear sapphire tips are about the size of a pin head and are rounded to prevent scuffing the paper. The jewel-tipped pens have an unlimited life expectancy and provide smooth operation.

For further information circle No. 1597 on literature request card, page 48-B.

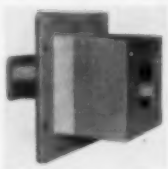
Controllers

The Wheelco Instruments Div. has announced two new nonindicating controllers. They are potentiometer-type units for control applications encountered in batch process work. They employ a circuit in which the unknown voltage is connected in opposition to a known voltage with any difference used to actuate the control circuit. The Model 151 Amplitrol is a simple on-off controller for those applications where transfer lag and dead time can be reduced to negligible value and the simplest of control forms made usable. The Model 152 is an anticipatory time-proportioning controller which compensates for system inertia. The contact rating of the new Wheelco 150 Series Amplitrol is 6 amp. at 115 volts a.c., 3 amp. at 230 volts a.c.

For further information circle No. 1598 on literature request card, page 48-B.

Burners

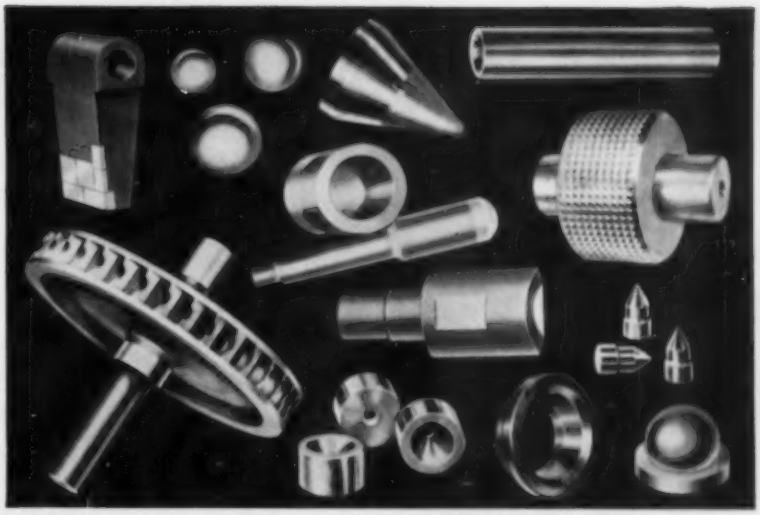
A new line of totally-enclosed tunnel-type gas burners for firing into pressurized combustion chambers has been announced by Bryant Industrial Products Corp. They are capable of effecting complete combustion in a furnace chamber pressurized up to 50 psi. Available in 18 sizes covering a capacity range from 4000 to 2,000,000 Btu. per hr., the new burners are designed to operate efficiently without special adjustment anywhere in the 450 to 3200 Btu. gas range.



For further information circle No. 1599 on literature request card, page 48-B.

Thermocouple Extension Wire

Minneapolis-Honeywell Regulator Co. has announced a new moisture resistant and flexible polyvinyl plastic insulated thermocouple wire in 14, 16 and 20 gage sizes. Each conductor is separately insulated with a 0.015-

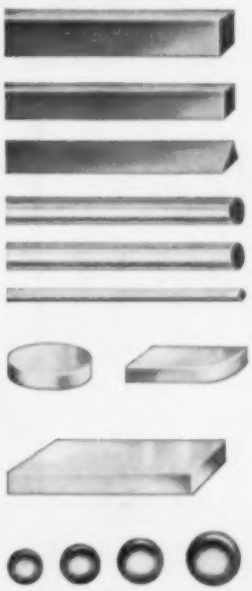


Where can you use these remarkable materials . . .

KENNAMETAL* and KENTANIUM*?

More than 40 different standard Kennametal compositions have been developed to provide exceptional durability and long life under conditions where any one or a combination of the following destructive forces are met:

- abrasion
- corrosion
- deflection
- deformation
- erosion
- galling
- hard impact or compression
- high temperature (1800°F and above)



Some of the many applications where these hard, strong and rigid sintered carbides are particularly effective in chemical processing include:

- balls for milling
- balls and seats for pumps
- bushings and guides
- compressor liners
- crusher parts
- mixer blades and parts
- nozzles
- pulverizing hammers
- turbine blades, rings, wheels
- valves, valve rings, valve seats

Kennametal is available in many standard forms, in addition to special shapes and parts, such as: rectangular blanks • discs • rods • tubes • flats • balls • rings • extruded, pressed, machined, and ground forms within precise tolerances.

Why not discuss your problems with your Kennametal carbide engineer. He can recommend the proper composition of Kennametal or high heat resistant Kentanium (for 1800° F and above) to meet your specific requirements. Or write KENNAMETAL INC., Latrobe, Pa. For more data, request booklet B-111, *Characteristics of Kennametal*, or B-222, *Designing with Kennametal*.

B-0000

*Trademark of a series of hard tungsten and titanium carbides which have exceptionally high resistance to destructive forces which tend to contaminate chemicals, foods, paints, and other products during processing.

INDUSTRY AND KENNAMETAL ...Partners in Progress

In This Leading Automotive Foundry, 500 to 600 tons of iron go through each of the big receiving ladles daily. A rammed lining of Norton ALUNDUM refractory cement, six inches thick, lasts 10 to 12 weeks, handling an average of 15,000 tons. Only occasional patching is required. The two-ton Crane monorail ladles handle 240 tons per day. Their linings of ALUNDUM cement, four inches thick, average 54 days of service life for a total tonnage of 13,000. About half these smaller ladles require patching, with the same Norton refractory material, after an average of 36 days' service.

Can your linings take this punishment?

Proof that ALUNDUM cement gives long life under heavy duty*

High-melting, long-lasting ALUNDUM cement is just one of many Norton ℞'s — refractories *engineered and prescribed* for longer, lower cost service across the range of furnace applications. Others include CRYSTOLON*, MAGNORITE*, and FUSED STABILIZED ZIRCONIA.

For ℞'s that will help maintain hot metal schedules and reduce shut-downs in your own furnaces, call in your Norton Refractories Engineer. Or write to NORTON COMPANY, 331 New Bond St., Worcester 6, Mass. *In Canada:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ontario.

Another Tough Spot for linings is this trough, in the same big automotive foundry. From 500 to 600 tons of molten iron pour through the trough every day. Bottom and sides, from dam to trough end, are lined with ALUNDUM cement. Average lining life is 11 to 12 days, during which approximately 6,000 tons of iron passes through.

NORTON

REFRACTORIES

Engineered... ℞... Prescribed

Making better products... to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories
BEHR-MANNING PRODUCTS: Coated Abrasives Sharpening Stones • Behr-cut Tapes
***Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries**

in. well of polyvinyl plaster and both are laid parallel and wrapped together with an additional 0.020 in. jacket of the same material. This insulation is easy to remove, will not support flame and is abrasion resistant.

For further information circle No. 1600 on literature request card, page 48-B.

Hydraulic Saw

The Loma Machine Mfg. Co. has announced an improved hydraulic saw for cutting heavy ingots. The new model features a saw carriage which travels on a cross beam above the ingot. This arrangement fully protects the moving parts, such as motor, carriage, saw blade drive and feed cylinder, from chips. The feed tables can extend close to the saw blade,

clamps are easily arranged on either side of the blade enabling short, last and first ends to be cut, and a mechanized chip conveyor may be placed below the saw blade for automatic chip removal. The entire operation cycle is remote-controlled.

For further information circle No. 1601 on literature request card, page 48-B.

Welded Aluminum Tubing

A new welded alloy tubing has been announced by the Jo-El Co. This tubing is available at any hardness, in light gages from under 0.050 to 0.025. It is designed for use in applications requiring material strength and weight reducton such as electrical conduit, television and radio antenna, furniture and heat exchangers. This aluminum tubing has easy workability and resists corrosion, most industrial atmospheres, many gases and liquids.

For further information circle No. 1602 on literature request card, page 48-B.

Gold Coatings

A new method of applying 22 carat gold coatings on ceramics, porcelain enamel and stainless steel has been announced by the Hanovia Chemical & Mfg. Co. The new heat treatment method is expected to put products

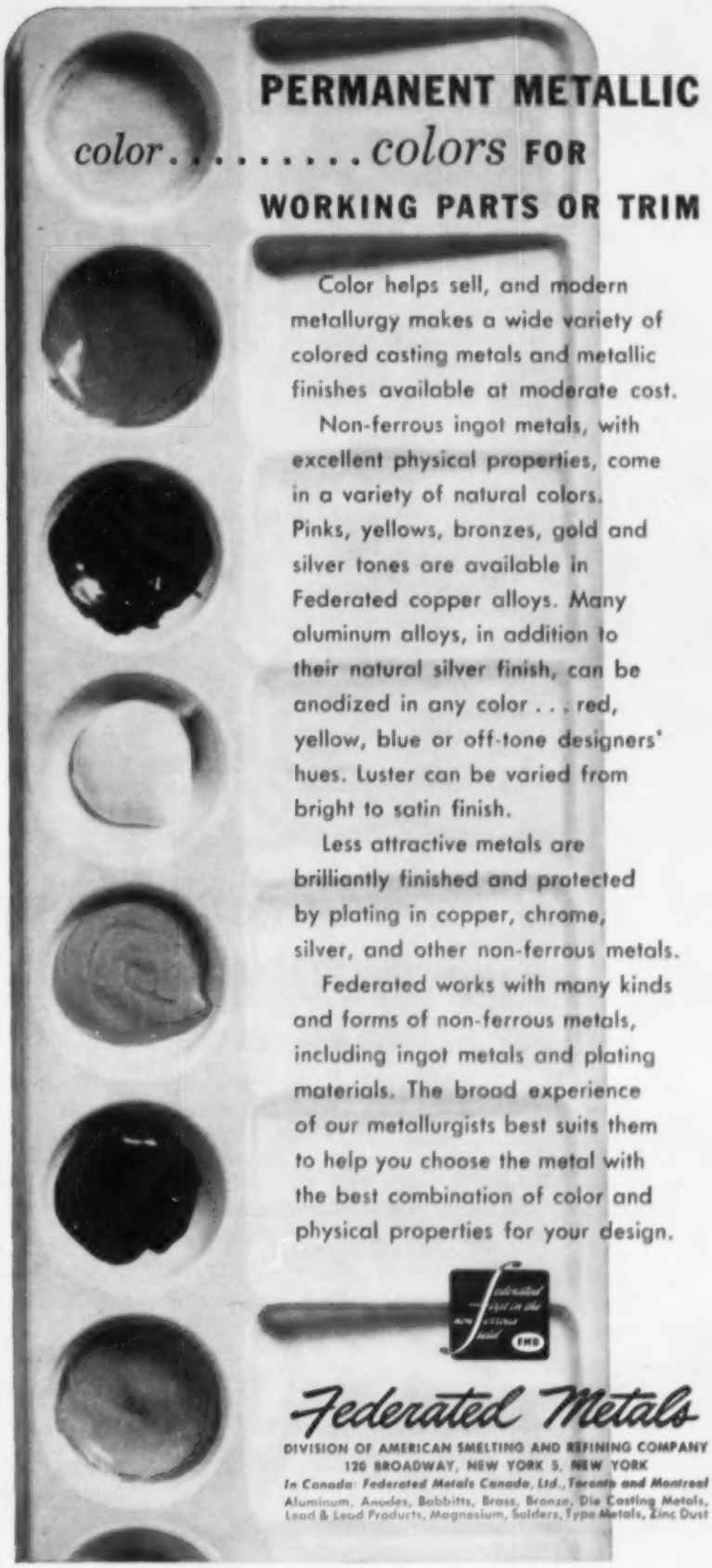

PERMANENT METALLIC
color . . . . . colors FOR
WORKING PARTS OR TRIM
Color helps sell, and modern metallurgy makes a wide variety of colored casting metals and metallic finishes available at moderate cost.
Non-ferrous ingot metals, with excellent physical properties, come in a variety of natural colors. Pinks, yellows, bronzes, gold and silver tones are available in Federated copper alloys. Many aluminum alloys, in addition to their natural silver finish, can be anodized in any color . . . red, yellow, blue or off-tone designers' hues. Luster can be varied from bright to satin finish.
Less attractive metals are brilliantly finished and protected by plating in copper, chrome, silver, and other non-ferrous metals.
Federated works with many kinds and forms of non-ferrous metals, including ingot metals and plating materials. The broad experience of our metallurgists best suits them to help you choose the metal with the best combination of color and physical properties for your design.
Federated Metals
DIVISION OF AMERICAN SMELTING AND REFINING COMPANY
120 BROADWAY, NEW YORK 5, NEW YORK
In Canada: Federated Metals Canada, Ltd., Toronto and Montreal
Aluminum, Anodes, Babbitts, Brass, Bronze, Die Casting Metals, Lead & Lead Products, Magnesium, Solders, Type Metals, Zinc Dust

TABLE II - PHYSICAL PROPERTIES OF HOUGHTON'S LIQUID BATHS

Type	Product	Melting Point °F.	Working Range °F.	Specific Heat (At Oper. Temp.)	Specific Gravity (At Oper. Temp.)	Unit Weight Liq. (lbs. per cu. ft.)	Liquidity (Drag-out gr. per sq. inch)
Liq. Carb.	Perliton Liq. Heat	1220	1350-1675	0.4-0.3	1.60 approx.	100 @ 1550	0.075-0.100 @ 1500 approx.
" "	" 11	1240					
" "	" 45	1210					
" "	" 60	1170	1350-1750	0.4-0.3	1.60 approx	100 @ 1550	0.075-0.100
Reheat	Perlitex 30	960	1050-1550	0.4-0.3	1.60 approx	100 @ 1400	0.017 @ 1450
"	" 50	940				95 @ 1400	0.013 @ 1450
"	" 75	1000				88 @ 1400	0.075 @ 1450
Carbonate	Liquid Heat 300	1040	1150-1700	0.442	1.90	119 @ 1500	0.025 @ 1500
Neutral	Liquid Heat N.D.	1200	1300-1700	0.171	2.65	165 @ 1550	0.075 @ 1500
"	" " 168	1240	1350-1650	0.263	1.60	100 @ 1350	0.020 @ 1500
"	" " 800	950	1025-1400	0.16	2.19	137 @ 1250	0.06 @ 1100
"	" " 980	980	1100-1650	0.158	2.24	140 @ 1250	0.04 @ 1250
"	" " 1145	1200	1300-1650	0.26	1.60	100 @ 1350	0.020 @ 1550
"	" " 1185	980	1050-1350	0.30	2.15	130 @ 1200	0.027 @ 1200
" (S.Stl)	" " 1450	1450	1550-1950	0.165	3.00	187 @ 1600	0.075 @ 1800
H.S. Steel	Liquid Heat 1550	1550	1650-2350	0.163	2.88	180 @ 2100	0.070 @ 2100
" "	" " Q-1138	875	920-1450	0.33	1.68	105 @ 1200	0.028 @ 1200
" "	" " 720	875	950-1450	0.28	1.83	114 @ 1200	0.03 @ 1200
Nitrate	Draw Temp 275	275	350-1000	0.36	1.76	110 @ 800	0.016 @ 900 0.052 @ 600
"	" " 430	430	550-1100	0.38	1.84	115 @ 800	0.017 @ 900 0.052 @ 600
"	Mar-Temp Salt	285	350-1000	0.36	1.92	120 @ 400	0.065 @ 400
Neutral	Draw Temp 800	950	1025-1400	0.16	2.19	137 @ 1250	0.06 @ 1100
Brazing	Liquid Heat 110	1450	1550-2100	0.166	3.01	187 @ 1600	0.075 @ 1800
"	Liquid Heat 111	1200	1300-1800	0.172	2.66	165 @ 1550	0.075 @ 1500

HEAT TREATING SALTS

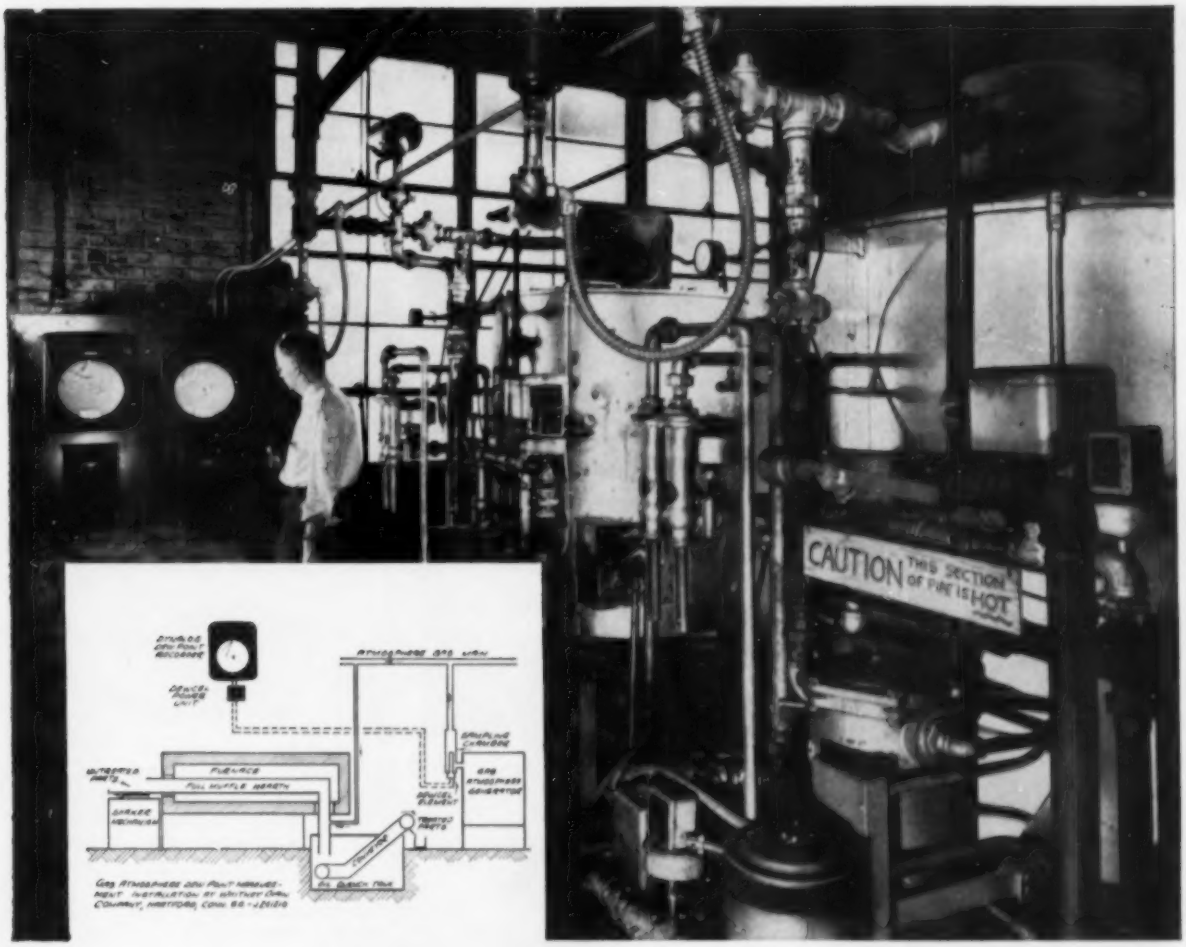
Add a dash of HOUGHTON "KNOW-HOW" and get the UNIFORM RESULTS you need!

• A valued ingredient that is not in the formula goes with every Houghton salt you buy—Houghton's wide knowledge of your heat treating problems.

It's the factor which adds extra assurance that your salt bath will be *right* for the job . . . that your heat treated metal will have the precise physical properties you require . . . that you'll be able to maintain the bath so as to get uniform results day after day.

In Houghton's 32-page "Liquid Salt Baths" book, you'll find proof of the benefits you get by using Houghton salts combined with Houghton experience. It shows you how to obtain faster, surer heat treating with salts. Ask the Houghton Man for a copy, or write to E. F. Houghton & Co., Philadelphia 33, Pa.

HEAT TREATING SALTS
... a product of
E F HOUGHTON & CO.
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO
Ready to give you on-the-job service . . .



Furnace Atmosphere Improved with **DEWCEL*** Moisture Measurement

Whitney Chain Co., in Hartford, Conn., uses two Gas-Atmosphere Generators to supply a battery of heat treating furnaces in producing chain plates, pins, rollers, and bushings for their Power Transmission and Conveyor Chains. Correct atmosphere conditions in the furnaces must be maintained for proper carbon control and retention of finish on these hardened and carburized parts.

Formerly it was necessary to make complicated time-consuming spot checks of these conditions. Now, *Foxboro Dew Point Recorders* monitor continuous samples of the gas from the generators . . . provide continuous dew point records which permit the operator to maintain desired gas quality.

The heart of this precise measuring system is its humidity-sensitive element — the exclusive Foxboro Dewcel which senses the dew point temperature to within ±1° F. . . . rapidly responds to any change in moisture content. Complete illustrated description of the Foxboro Dew Point Recording System is contained in Engineering Data Sheet 340-7. Write for copy.

*Trade Mark

THE FOXBORO COMPANY, 5212 NEPONSET AVE., FOXBORO, MASS.

FOXBORO
REG. U. S. PAT. OFF.

INSTRUMENTS that Improve Product Quality

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

ROLOCK
FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

FURNACE TRAYS operating with 100 to 1 load-to-weight ratio . . .

again prove soundness of **ROLOCK** design and **SERPENTINE** construction

Rolock time-tested "Serpentine" design and welded fabricated articulated construction solved a particularly difficult problem in these big annealing furnace tray units . . . since they are rail-supported on roller wheels, as shown in the upside-down photograph at right.

Original specifications called for only 12,000-lb. tray loads, but operating schedules have imposed 50,000-lb. loads, with each tray also required to *pull* two other loaded units through the furnace. Size of trays: 20' 10" long x 18" wide. Material: Stainless Steel. Temperature: 1500° F. Rolock Serpentine articulated construction permits required expansion and contraction, assures maximum service life.

Numerous equally successful variations of these Rolock Serpentine tray designs have been developed for box-type and continuous furnaces with other types of hearths. If you have a similar problem, Rolock specialists can definitely promise you economies. Write us.

SALES AND SERVICE REPRESENTATIVES FROM COAST TO COAST

ROLOCK INC., 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

ERLSS

with a genuine gold finish within reach of the middle income consumer. The new method can be used for store fronts, lettering on porcelain enamel, for trade marks and emblems on appliances and for architectural finishes.

For further information circle No. 1603 on literature request card, page 48-B.

Selenium Rectifier

A combination selenium rectifier rated at 100 amp., 0 to 6 volts d.c., with periodic current reverser has been announced by Rapid Electric Co. This newly designed model measures 19 by 22 by 18 in. and combines a standard, full control plating rectifier with periodic current reversal. Periodic current reversal is independent of the plating rectifier and both can be used separately. Pilot lights indicate direction of current at all times.

For further information circle No. 1604 on literature request card, page 48-B.

Blast Cleaning

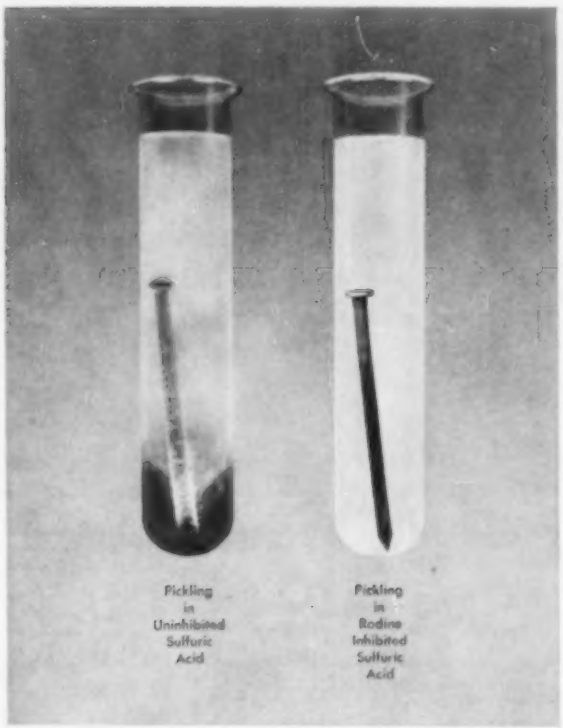
A special tooling adaptation to one of its line of standard, manually operated pressure blast machines has been announced by the Cro-Plate Co. The workpiece is loaded on the drawer-type slide at the outside and pushed through a baffled area into the interior. A variable speed drive is actuated and rotates the roller cage at approximately 12 to 15 r.p.m. An air-drawlic cylinder is energized by the same slide motion and a series of blast guns are oscillated over appropriate areas of the workpiece.

For further information circle No. 1605 on literature request card, page 48-B.

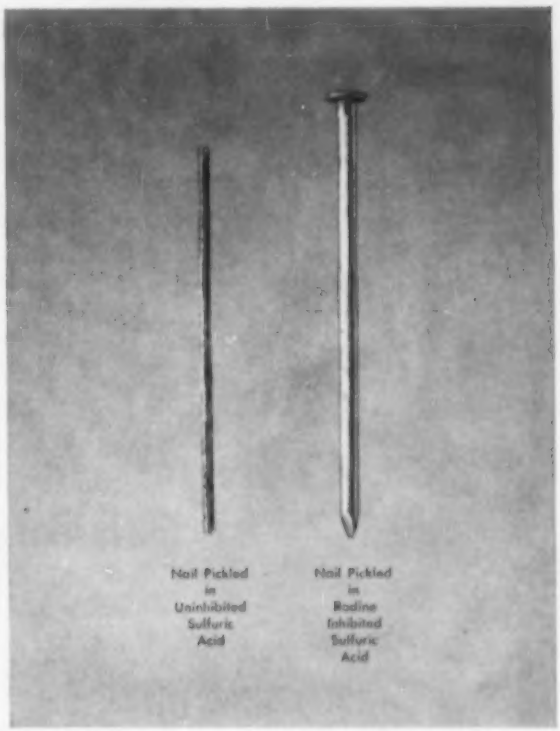
HOW RODINE® CUTS PICKLING COSTS

Tests demonstrate the effectiveness of Rodine in retarding the attack of acid on the metal

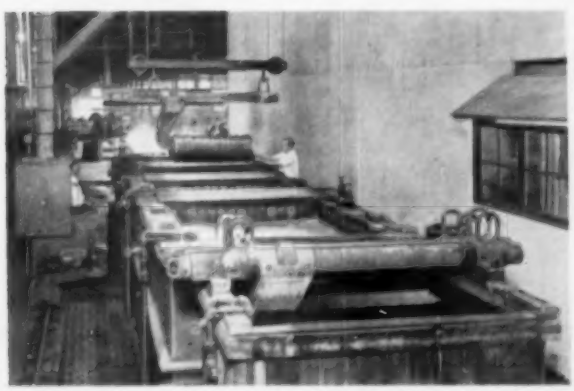
Rodine pickling acid inhibitors retard the attack of the acid on the metal without affecting the ability of the acid to remove scale. Their effectiveness in saving acid and metal is demonstrated by these two simple tests:



Formation of Hydrogen Test. Both test tubes contain a 10% by volume solution of sulfuric acid. In the left-hand tube, the acid is uninhibited. In the right-hand tube, a Rodine inhibitor has been added in an amount equal to 1% by volume of the concentrated acid. There is no bubbling in this tube—Rodine has retarded the formation of hydrogen that is the result of acid dissolving steel.



Loss of Weight Test. Both nails have been pickled in a 10% by volume solution of sulfuric acid for the same length of time. The nail pickled in the uninhibited sulfuric acid solution has lost its form, does not look like a nail any more. The nail pickled in the sulfuric acid solution with Rodine added has lost little weight, has retained its shape and luster.



Rod and wire, tube and sheet are pickled clean with Rodine, without wasting either acid or metal—there are fewer rejects, which means big savings.

Not only does Rodine save metal and acid, but it improves the quality of the pickled product as well. And baths containing Rodine can be operated longer with less acid required to keep them at the desired concentration.

Our treatise on pickling and the use of Rodine, "Efficient Pickling with Rodine," gives full information. Send for your copy today—it makes profitable reading.

AMERICAN CHEMICAL PAINT COMPANY
Ambler 16, Pa.

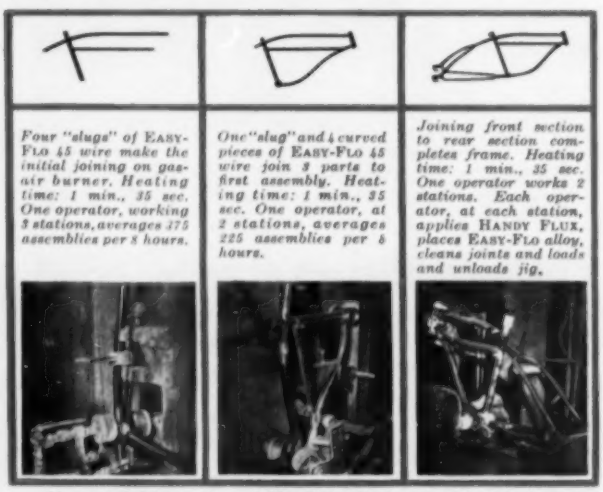
DETROIT, MICHIGAN
NILES, CALIFORNIA
ST. JOSEPH, MISSOURI
WINDSOR, ONTARIO

CHEMICALS ACP PROCESSES

Here's Why Columbia Bicycle Frames Are EASY-FLO BRAZED

The *speed* and *economy of labor* enjoyed with EASY-FLO silver brazing of tubular assemblies of all kinds are outstanding. The old method used by Columbia required 42 men to grind fillets and clean the brazed joints on 1000 frames a day. Now, with EASY-FLO and HANDY FLUX, 3 men do the finishing on the same number of frames. Five pieces of curved wire and five small slugs of EASY-FLO 45 are used to produce a frame that is as strong and indestructible as though it were one piece.

Here is the "joining sequence" of one of the many models of Columbia frames.



Four "slugs" of EASY-FLO 45 wire make the initial joining on gas-air burner. Heating time: 1 min., 35 sec. One operator, working 3 stations, averages 375 assemblies per 8 hours.

One "slug" and 4 curved pieces of EASY-FLO 45 wire join 3 parts to first assembly. Heating time: 1 min., 35 sec. One operator, at 2 stations, averages 225 assemblies per 8 hours.

Joining front section to rear section completes frame. Heating time: 1 min., 35 sec. One operator works 2 stations. Each operator, at each station, applies HANDY FLUX, places EASY-FLO alloy, cleans joints and loads and unloads jig.

Photos and data courtesy of The Westfield Manufacturing Company, Westfield, Mass., makers of Columbia Bicycles.

GET COMPLETE EASY-FLO FACTS AND DISTRIBUTOR LIST.

BULLETIN 20 explains why high strength, speed and economy are inherent in EASY-FLO brazing. Also gives Handy information about joint design and fast brazing methods. Get your copy, with distributor list, by writing today.

Your NO. 1 Source of Supply and Authority on Silver Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

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TORONTO, CANADA
MONTREAL, CANADA

APPLICATION and EQUIPMENT new literature

1610. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

1611. Alloy Cast Iron
64-page bulletin A-71 on engineering properties and applications of Ni-Resist. Corrosion data compared with gray cast iron. *International Nickel Co.*

1612. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

1613. Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

1614. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

1615. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

1616. Alloy Steel
Comparative tables of SAE and AISI standard steels and tentative standard steels. *Babcock & Wilcox*

1617. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1618. Alloy Steel Castings
Specifications for T-loy 34 and T-loy 42. Heat treatment and characteristics. *Unitcast Corp.*

1619. Aluminum Alloys
New 61-page book on aluminum casting alloys, their characteristics and behavior. Specifications of government agencies and technical societies. *Alloys & Chemicals Mfg. Co.*

1620. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1621. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

1622. Ammonia Atmospheres
12-page bulletin B-52 on dissociated ammonia furnace atmospheres. *Drever*

1623. Arc Welder
20-page catalog on new submerged arc welders, A.c., d.c., field machines and accessories. *Lincoln Electric Co.*

1624. Atmosphere Furnace
Information on mechanical batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

1625. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

1626. Atmosphere Furnaces
4-page bulletin on furnaces for hardening high carbon and high speed tool steels. Diagrams, specifications and performance data. *Lindberg Engineering Co.*

1627. Atmospheres
8-page booklet N-91-620(1) on infrared equipment to monitor CO, CO_2 or CH, content of metallurgical atmospheres. *Leeds & Northrup.*

1628. Atmospheres
12-page booklet on design and use of special atmospheres for industrial furnaces. *Continental Industrial Engineers*

1629. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

1630. Bimetal Applications
New 44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1631. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

1632. Blast Cleaning
New 8-page brochure No. 607 on air blast cleaning cabinet. Tables give dimensions and specifications. *Pangborn*

1633. Blast Cleaning
New 56-page catalog on semi-automatic and automatic pressure wet-blast equipment. Applications. *Cro-Plate Co.*

1634. Bonding Plastics
New literature on new method of bonding Teflon and Rulon by surface treatments. *Dixon Corp.*

1635. Boron
16-page book on boron carbide, elemental boron and other boron-rich materials. Property data, sizing of powders, manufacture, uses. *Norton*

1636. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

1637. Brass
8-page publication B-39 on fine-grain drawing brass. Case histories. *American Brass*

1638. Brazed Assemblies
New 4-page catalog on facilities for design, development and manufacture of copper and silver brazed assemblies *Wall Colmony*

1639. Brazing
28-page catalog of brazing and soldering equipment with suggestions on setting up brazing lines to fit the product being joined. *C. M. Kemp*

1640. Brazing
8-page bulletin S-1050 on production brazing and soldering. Automatic brazing machine. *Selas Corp.*

1641. Brazing Alloys
Bulletin 22 on high-temperature brazing alloys for stainless steel and heat-resistant alloys. *Handy & Harman*

1642. Burners
Bulletin 58 on gas burners shows design and installation arrangements. Table of capacities. *North American Mfg.*

1643. Burners
32-page catalog on industrial gas burners and gas furnaces for heat treating carbon and alloy steels. Pot furnaces and melting furnaces. *Charles A. Hones*

1644. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

1609. Forgings
The chemical, mechanical, physical and forging characteristics of brass, bronze, copper and aluminum alloys are tabulated in this

new 36-page forging booklet. Also of value are the table on tolerances, the definitions of forging terms, and the discussion of factors to be considered in design of forgings. *Titan Metal*

1645. Carbides
76-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

1646. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

1647. Carbon Control
Bulletin SC-168 on system for automatically controlling carbon potential in continuous and batch furnaces. *Surface Combustion Corp.*

1648. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs. time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

Measure Coating Thicknesses ACCURATELY & NON-DESTRUCTIVELY

METAL Coatings on

IRON, STEEL and

NICKEL Coatings

MAGNE-GAGE

The Magne-Gage quickly and accurately measures thickness of coatings such as the following:

1. Nickel coatings up to 0.001 in. thick on non-magnetic base metals, such as copper, brass, and zinc-base diecastings.
2. Polished nickel coatings up to 0.002 in. thick on iron or steel.
3. Non-magnetic coatings up to 0.080 in. thick on iron or steel. Such coatings may be electro-deposited copper, zinc, cadmium, tin or chromium; hot-dipped tin, zinc or lead; non-metallic paint or vitreous enamel.

Instrument is portable—measures curved as well as flat surfaces—accuracy within ±10%. Complete readings can be made in 45 seconds.

Coatings of

PAINT, VARNISH, SHELLAC,

CERAMICS, PLASTICS, ANODIC

FILMETER

Thickness of non-conducting coatings on non-magnetic base metals (aluminum, duralumin, brass, copper and bronze) are readily measured by the Filmeter. Coatings in this category include paint, varnish, shellac, lacquer, enamel, plastics, and ceramics from 0 to 0.005 in. thick.

The Filmeter measures with an accuracy of ± 3% of full scale. Measurements can be made on flat, concave or convex surfaces.

The instrument will measure anodized films from 0 to 0.001 in. thick, on aluminum, or aluminum alloys in accordance with ASTM Test No. B244-49T.

Device includes an inductor which is placed on the coated surface; a control box, a set of earphones, standard thickness samples, and a calibration chart. The instrument weighs only 11 lb., is battery-operated and fitted with a carrying strap.

Specified by ASTM For Test 1400-56T

The Filmeter has recently been recommended by the ASTM (American Society for Testing Materials) as the instrument to perform Test No. 1400-56T, "Method for determining the dry-film thickness of non-metallic coatings of paint, varnish, lacquer and related products on a non-magnetic metal base."

Full information for both instruments contained in **BULLETIN 2253-J,** *furnished on request*

AMINCO

AMERICAN INSTRUMENT COMPANY, INC.

Silver Spring, Maryland

In Metropolitan Washington, D. C.

1649. Carburizing
Basic principles of quality gas carburizing in Heat Treat Review, Vol. 7, No. 2. *Surface Combustion*

1650. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

1651. Ceramic Tools
10-page report on machining steel with ceramic tools includes grinding ceramic tools, new-type tool holder, geometry of ceramic tools. *Norton*

1652. Chain Curtains
12-page booklet on chain furnace curtains tells how and where they can be used. *E. J. Codd*

1653. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1654. Chromium Plating
4-page bulletin on new "crack-free" chromium plating process. *United Chromium Div., Metal & Thermit*

1655. Chromizing
4-page folder describes how to make iron powder components resistant to rust and wear. *Chromalloy Corp.*

1656. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

1657. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

1658. Cutting Oil
Bulletin 39 on transparent cutting oil which is designed for use on a wide variety of steels. *Sun Oil Co.*

1659. Cleaner
12-page bulletin on advantages of Immunol, how to use it, applications. *Harry Miller Corp.*

1660. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

1661. Cleaning
12-page Technical Letter No. 11 gives recommended surface preparation of steel for red lead paints. *Lead Industries*

1662. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning", discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

1663. Cleaning
Folder on di-phase cleaning gives equipment, construction features, spray and blow-off features, heating systems. *Solventol*

1664. Coatings
Bulletin on coatings of tungsten carbide. Preparing parts for fusecoating. Allowances for distortion. *Fusion Metal Coating Co.*

1665. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

1666. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

1667. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

1668. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1669. Constructional Steels
Booklet on Yoloy E steel describes and gives properties of high-strength low-alloy steels. *Youngstown Sheet and Tube*

1670. Controllers
12-page booklet on temperature controls and special purpose controllers. Operation, design, installation. *Assembly Products, Inc.*

1671. Controllers
Specification S-152-2 on proportional control instruments for use with thermocouples. *Minneapolis-Honeywell*

1672. Copper Alloys
60-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside Metal*

1673. Corrosion Resistance
20-page bulletin on copper alloys for corrosion resistance. Table gives applicability in 150 media. *Ampco*

1674. Creep Testing
Bulletin RR-13-54 on new creep testing machine. *Riehle*

1675. Degreasing
New bulletin on OPNT vapor degreaser describes and diagrams its construction. *Circo Equipment*

1676. Descaling
Bulletin on system of descaling stainless, alloy steels and titanium after heat treating. *Kolene Corp.*

1677. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

1678. Descaling Titanium
Bulletin 25-T on salt descaling of titanium and titanium alloys. History, recommended procedure, problems. *Hooker Electrochemical*

1679. Dew-Point Recorder
Bulletin 11-11 on dew-point systems for recording or controlling. *Foxboro*

1680. Dies
48-page manual on power press brake dies describes those in most common use and special purpose dies. Tables of sheet gages and weights. *Cyril Bath Co.*

1681. Ductile Iron
New 28-page bulletin gives advantages and applications of ductile iron. Properties. *International Nickel Co.*

1682. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

1683. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1684. Electric Furnaces
Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

1685. Electric Furnaces
Catalog of electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

1686. Electrodes
New 16-page catalog on spectroscopic electrodes and powders. How purity is secured and maintained. *National Carbon*

the ONLY
PORTABLE NIBBLER *that* **CUTS**
10 Gauge Steel

Model NN for 10 gauge Stainless Steel and 8 gauge Mild Steel. 6" radius.

Without Distortion!

A big statement ... and only Fenway can make it! Our portable Nibblers have solved unusual problems for hundreds of users. Complete line includes the 14 gauge Nibbler and a light-duty 18 gauge Nibbler, and a special 90° head for each.

RCA—DU PONT—GENERAL MOTORS—and many others, use Fenway Portable Nibblers!

PAT. #2278174 #2278311 #2535631

Model MN for 14 gauge Stainless Steel and 13 gauge Mild Steel. 1" radius.

ALSO AVAILABLE: CORRUGATED, JIGSAW ASSEMBLY & AIR TOOLS

WIRE • PHONE • WRITE for complete information

FENWAY
MACHINE COMPANY INC.
Edgemont & Clementine Sts.
Philadelphia 34, Penna.

Distributed by EASCO PRODUCTS

XVIII

This is the eighteenth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Methods of Carburizing Alloy Steels

Carburizing is a means of impregnating the surface of steel with carbon, usually to very limited depths. Its purpose is to provide a hard, wear-resisting "case," or outer shell. Alloy steels, correctly handled, can be case-hardened without sacrificing desirable core properties.

There are three types of carburizing in general use. These will be discussed briefly in the following paragraphs:

Liquid Carburizing—The medium here is a hot salt bath composed basically of cyanide compounds. The steel is immersed in the bath, the period of immersion depending upon the analysis of the steel and the depth of case desired. Liquid carburizing produces a thin, hard, wear-resisting case with a maximum practical depth range of 0.02 to 0.03 in. When the steel is quenched directly from the bath, distortion is low.

Gas Carburizing—This method employs a furnace in which a carbonaceous atmosphere is created; i.e., gases that are high in carbon components, or those containing carbon. Steel subjected to gas carburizing can be case-hardened to depths generally ranging from 0.01 to 0.04 in. When quenching takes place immediately after carburizing, distortion can be kept to a minimum.

Pack Carburizing—Where the pack method is used, the parts to be carburized are buried in a container of dry carbonaceous materials. The container is sealed tight to prevent the infiltration of air, placed in a furnace and kept there for eight hours or more, the actual time depending upon the depth of case desired. Pack carburizing is particularly suitable where a deep case is essential (0.06 in. and over), although medium cases in the 0.04-to-0.06-in. range are possible.

The carburizing of alloy steels is a highly technical subject, and Bethlehem metallurgists will be glad to help you with any phase of it. Feel free to consult with them about the results to be expected from various analyses and the various methods of treatment. And when you are in the market for alloy steels of any kind, please bear in mind that Bethlehem Steel makes the complete range of AISI standard grades of alloy steels, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XVI please write to us, addressing your request to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. The first 16 subjects in the series are now available in a handy 32-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

1687. Electrolytic Metals
New 4-page folder on analysis and specifications of electrolytic chromium and manganese. Uses and properties. *Electro Metallurgical Co.*

1688. Electron Microscope
20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

1689. Electroplating
"Industrial Precision Electroplating" tells of facilities for metal finishing, growth and advancements of metal finishing, requirements of specific industries. *Summit Finishing Co.*

1690. Endothermic Atmospheres
16-page reprint on endothermic atmospheres for heat treatment of steel. Effect of temperature on atmosphere. Calculating analysis. *Electric Furnace Co.*

1691. Fabricating Stainless
8-page reprint on low-nickel, high-manganese steels and their fabrication. *International Nickel Co.*

1692. Filters
4-page reprint on plating waste disposal with special emphasis on precipitation and filtration. *Filtration Engineers*

1693. Finishing
Six bulletins describing finishing compounds for stainless steel, aluminum, other metals. *Apothecaries Hall*

1694. Flow Measurement
8-page Bulletin SC-1022 on instrument for measurement of flow rate of air and gases. *Selas Corp.*

1695. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

1696. Fluid-Power Tubing
8-page bulletin provides engineering data on four types of cold finished steel tubing for hydraulic cylinders and fluid lines. *Ryerson*

1697. Forgings
8-page bulletin on closed die forgings gives forging sizes, forging stock and shapes. *Indiana Forge and Machine*

1698. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A Finkl*

1699. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1700. Forgings
New 12-page booklet on aluminum, brass and copper forgings. Parts forged and their advantages. Properties of alloys used. *Revere Copper & Brass*

1701. Forgings
8-page brochure on precision forging of different sizes and metals. *Titusville Forge Div., Struthers Wells Corp.*

1702. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1703. Furnace Controls
44-page condensed catalog of controls for industrial furnaces and ovens. *Minneapolis-Honeywell Regulator Co.*

1704. Furnace Fixtures
16-page catalog on baskets, trays, fixtures, and carburizing boxes for heat treating. 66 designs. *Stanwood*

1705. Furnaces
Series of bulletins on controlled atmosphere, carburizing, nitriding, hardening furnaces. *American Gas Furnace*

1706. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

1707. Furnaces
32-page catalog of industrial equipment includes furnaces and furnace equipment, special valves, mechanical equipment, materials handling equipment. *Salem-Brosius*

1708. Furnaces
Box furnace with cooling chamber for use to 3100° F. described in bulletin GEA-4713. *General Electric*

1709. Furnaces
Brochures on pot furnaces, nitriding, austempering, and martempering and salt baths. *A. F. Holden*

1710. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1711. Furnaces
New vacuum furnace bulletin. *National Research Corp.*

1712. Fused Silica
Folder on fused silica which is resistant to high temperatures, thermal shock, acids and has high electrical insulating value. *Amersil*

1713. Galvanometers
12-page bulletin No. 320 on three different types of galvanometer. Factors affecting selection. *Rubicon*

1714. Gamma Ray Sources
24-page booklet on portable gamma ray projectors, using cobalt 60, cesium 137, iridium 192. Operation and construction features. *Metal & Thermit Corp.*

1715. Gas Analysis
New 16-page booklet TD-507 on instruments for continuous analysis. *Arnold O. Beckman, Inc.*

1716. Gas Analysis
Bulletin 11-11 on portable and continuous instruments for detection and measurement of combustible gases and vapors, oxygen, toxic gases and gas proportioning and control. *Davis Instrument*

1717. Gas Purifiers
Folder on 6 gas purifiers and indicators for the catalytic purification, hydrogenation and oxidation of gases. *Baker & Co.*

1718. Globar Furnaces
Bulletin 153 describes nine types of furnace using silicon carbide heating elements for temperatures to 2600° F. *Hevi Duty*

1719. Gold Plating
Physical, thermal, chemical, electrical, diffusion and optical properties of electroplated gold. Uses. *Technic, Inc.*

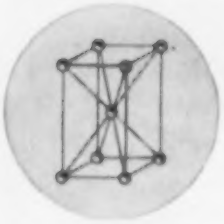
1720. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

1721. Graphite
Bulletin No. 20 on carbon-graphite engineering material, manufacturing process, properties, uses. *U.S. Graphite*

1722. Graphitic Tool Steel
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

1723. Grinding Wheels
Folder on grinding wheel especially adapted for use in steel mills shows structure and gives advantages. *Sterling Grinding Wheel Co.*

1724. Hardening Tool Steels
4-page bulletin on complete line of



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hydrizing furnaces. Diagrams, specifications and performance data on preheat and high speed furnaces. *Lindberg Engineering*

1725. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

1726. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1727. Hardness Testers
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1728. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

1729. Hardness Testing
Bulletins on Wolpert-Gries machines for standard Rockwell tests. Motorized reflex type for Brinell tests. *Gries Industries*

1730. Heat Treating
Bulletin 441 on box-type electric furnaces diagrams and describes the furnaces and lists specifications. *Hevi Duty Electric Co.*

1731. Heat Treating
New 8-page catalog SC-175 on 27 standard heat treat furnaces from laboratory furnaces to large continuous brazing furnaces. *Surface Combustion*

1732. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

1733. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex.*

1734. Heat Treating Fixtures
32-page Catalog G-10 covers heat and corrosion resistant fabricated alloy products. Includes furnace muffles, tray, fixtures, retorts, pit-type furnace equipment, salt bath equipment, pickling and plating equipment. *Rolock, Inc.*

1735. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1736. Heat Treating Furnaces
12-page bulletin on recirculating furnaces for heat treating aluminum alloys, annealing and stress relieving. Conveyorized, pot and batch types. *Despatch*

1737. Heat Treating Pots
6-page bulletin lists sizes available in Thermalloy. Suggestions on increasing service life. *Electro-Alloys*

1738. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

1739. High Speed Steel
Folder on Electrite Double Six M-2 XL tungsten-molybdenum high speed steel containing alloy sulphides for improved machinability and increased tool life. *Latrobe Steel Co.*

1740. High-Strength Bronze
12-page booklet on telnic bronze with high strength, high hardness, good machinability, age hardenability, corrosion resistance. *Chase Brass*

1741. High-Temperature Lubrication
Bulletin 423 on colloidal graphite and molybdenum disulfide dispersions and their use for high-temperature lubrication. Case histories. *Acheson Colloids*

1742. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U.S. Steel*

1743. High-Temperature Tubing
Bulletin TDC-163A on analysis, properties, creep and rupture data for various tubing alloys for high temperature service. *Babcock & Wilcox*

1744. Induction Hardening
Bulletin M-1938 on induction hardening machine gives advantages and application of system. *Cincinnati Milling Machine*

1745. Induction Heating
New 36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

1746. Induction Heating
12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

1747. Induction Heating
8-page bulletin on high frequency motor-generator sets for induction heating. *Ohio Crankshaft*

1748. Industrial Equipment
12-page catalog on finishing systems, cleaning, pickling, rustproofing equipment, ovens, conveying equipment. *R. C. Mahon Co.*

1749. Ingot Stripper
Folder on operation and functions of portable hydraulic ingot stripper. Diagrams of two standard sizes. *Pittsburgh Engineering & Machine Co.*

1750. Inspection
Descriptive information and instructions for new inspection process to detect surface flaws on all ferrous and nonferrous metals. *Zaco Laboratories*

1751. Instruments
32-page catalog of instruments for analysis, control and data processing. *Consolidated Electrodynamics Corp.*

1752. Investment Casting
27-page reprint tells of development and applications of Shaw process of precision casting. *Shaw Development*

1753. Investment Casting
12-page brochure on the process, shapes which may be cast, tolerances, assembly savings. *Investment Casting Co.*

1754. Laboratory Equipment
Bulletin No. 832 on connecting and valving devices for gas, vapor and liquid flow systems of analytical instruments. *Burrell Corp.*

1755. Laboratory Furnace
Bulletin 1016 on single and dual tube furnaces for combustion analysis. *Sentry*

1756. Low-Alloy Steel
60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U.S. Steel*

1757. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

1758. Lubricant Testing
Bulletin 106 on new testing machine for lubricants. Operation and specifications. *Alpha Molykote Corp.*

1759. Machining Stainless
16-page booklet on drilling, tapping, thread chasing, turning, milling, broach-

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ing. Machinability rating of stainless steels. *Crucible Steel Co.*

1760. Magnesium Alloys
Loose-leaf folder of data and tables on chemical specifications, properties, extrusion, machining operations. *Brooks and Perkins*

1761. Magnesium Dust
8-page brochure on methods of collecting and controlling magnesium alloy dust and fumes. *Peters-Dalton*

1762. Magnesium-Zirconium
10-page reprint on an investigation of zirconium chloride, zirconium fluoride, 40% zirconium-magnesium material for making magnesium zirconium alloys. *Titanium Alloy Mfg. Div.*

1763. Metal Powders
8-page bulletin 561 gives specifications, properties and uses of metal powders. *Metals Disintegrating Co.*

1764. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1765. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

1766. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

1767. Moisture Measurement
12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

1768. Molybdenum
8-page reprint on arc-cast molybdenum describes machining procedures, tools and equipment. How to machine a turbine wheel. *Climax Molybdenum Co.*

1769. Nickel Alloy
12-page booklet on Hastelloy Alloy R-235, vacuum-melted wrought alloy containing aluminum and titanium. *Haynes Stellite Co.*

1770. Nitriding
Data on process for nitriding stainless steel. *Standard Steel Treating*

1771. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1772. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1773. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1774. Ovens
Bulletin 10-S on cabinet ovens describes those for use with gas, electric and steam heat for temperatures to 600° F. *Young Brothers*

1775. Ovens
16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl-Mayer*

1776. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1777. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1778. Plating
Folder on electroplating with metal fluoborate solutions—lead, tin, iron, copper, nickel, cadmium and indium. *Baker & Adamson*

1779. Plating Solutions
Operating manuals for plating with metal fluorborate solutions. *Baker & Adamson.* See page 55

1780. Polishing Materials
20-page booklet includes samples of emery, aluminum oxide and silicon carbide papers and 12 polishing cloths. *Buehler, Ltd.*

1781. Powdered Iron
Properties of Plast-Iron with and without copper. *Plastic Metals Div.*

1782. Powdered Metals
Data sheets on sintered iron, steel, brass alloys, bronze alloys and bronze filters. *Dixon Sintaloy, Inc.*

1783. Precision Casting
Fact Sheet tells what Shaw process is, what alloys can be used, equipment, tolerances, and shows examples of investment castings. *Shaw Process Development*

1784. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1785. Product File
30 new products and 500 pieces of literature described in 20 page reprint of items appearing in monthly magazine during fourth quarter. *Metal Progress*

1786. Pyrometer Calibration
"Pyrometer Thermocouple Calibration Data" includes tables of data released by National Bureau of Standards. *Bristol Co.*

1787. Pyrometers
32-page thermocouple and accessory bulletin. *West Instrument*

1788. Pyrometers
Catalog 168 on surface pyrometer for surface and subsurface temperature readings. *Pyrometer Instrument*

1789. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

1790. Quenching.
16-page booklet on modified and full marquenching procedures. Hardness and dimensional control data, cooling curves, case histories. *Sinclair Refining Co.*

1791. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

1792. Quenching
64-page book tells what happens when steel is heated and cooled, describes quenching media, quenching practices, interrupted quenching and cooling methods. *E. F. Houghton*

1793. Radiation Detection
Data bulletins on cells give their advantages, describe two models and explain engineering principles. *Servo Corp.*

1794. Radiation Products
8-page catalog on equipment for nuclear research. Radioactive sources, shielding and exposure equipment, instruments, services. *Budd Co.*

1795. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting." *Molybdenum Corp.*

(Continued on page 48-A)

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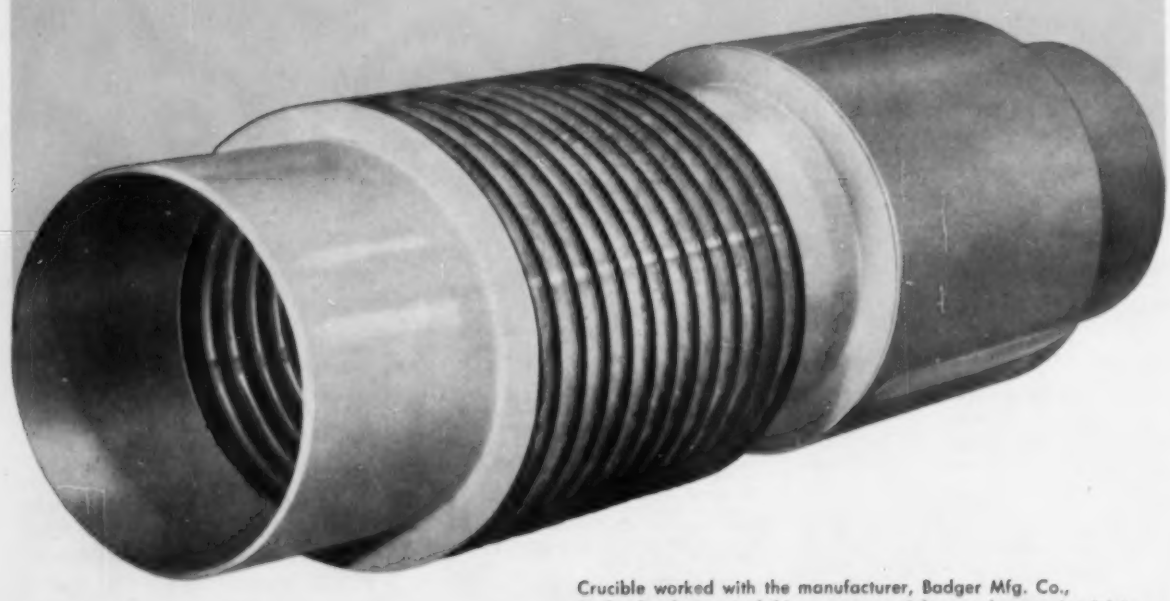

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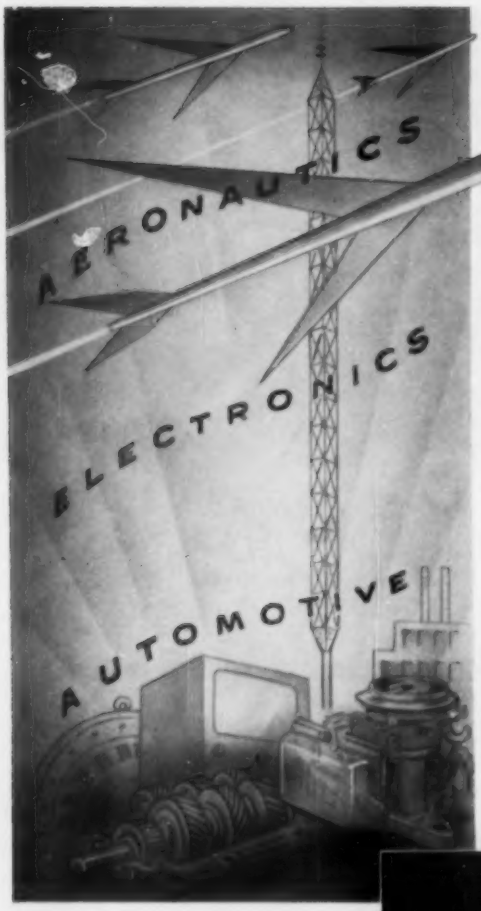

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(Continued from page 45)

1796. Refractories
8-page bulletin on castable refractories tells how to apply, properties, how much to use and where to use them. *Refractory & Insulation Corp.*

1797. Refractories
8-page catalog of fired refractory materials. 19 standard brands are classified and discussed as to properties and applications. *Richard C. Remmey Son Co.*

1798. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for service to 3000° F. *Johns-Manville*

1799. Refractory Cement
New 8-page folder on heavy duty brick bonding and patching mortar. How it is used. Service reports. *Refractory & Insulation Corp.*

1800. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

1801. Refractory Metals
24-page booklet on tungsten, molybdenum, tantalum, their properties and uses. *Fansteel Metallurgical Corp.*

1802. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1803. Rolling Mills
Catalog on line of machines for rolling ferrous and nonferrous metals gives descriptions and lubrication and maintenance instructions. *Fenn Mfg. Co.*

1804. Rotary Knives
New bulletin on various types of slitting knives and other tools designed for unusual requirements. *Cowles Tool Co.*

1805. Rust Preventives
12-page bulletin on water-soluble rust preventive. *Production Specialties*

1806. Rust Removal
Booklet on stripper for removal of rust, paint, phosphate coatings and other soils. *Metasurf Corp.*

1807. Salt Bath Furnace
Bulletin 655 on immersed electrode salt bath furnace gives advantages, applications, construction. *Hevi Duty*

1808. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1809. Sand Control
32-page book on defects and troubles in foundry and how to remedy them through sand control. *Claud S. Gordon*

1810. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1811. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

1812. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

1813. Slitter
New 16-page booklet on rotary gang slitters. Sheet and coil slitting methods summarized. *Stanat Mfg.*

1814. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1815. Soldering Flux
New 2-page bulletin on use of liquid rosin flux in electrical, electronic and printed circuit soldering. *Alpha Metals*

1816. Specification Key
Guide to Government specifications for phosphatizing, rustproofing and paint bonding chemicals. *American Chemical Paint*

1817. Spectrograph
24-page booklet on Echelle spectrographs. Advantages. Type of work produced. *Bausch & Lomb*

1818. Spectrographic Supplies
20-page catalog on special pure materials and alloy standards, plates and films and graphite electrodes and powders. *Jarrell-Ash*

1819. Spectroscopes
New catalog on diffraction, prism, reversion and ultraviolet spectroscopes and accessories. *Ealing Corp.*

1820. Stainless Steel
12-page booklet on new AM 350 chromium-nickel-molybdenum stainless steel which is hardenable by subzero cooling or double aging. *Allegheny Ludlum*

1821. Stainless Steel
Booklet on 430 stainless. Properties, fabrication. *Sharon Steel.*

1822. Stainless Steels
16-page booklet on heat treatment of stainless steels. Operating data for annealing and handling. Physical property data. Pickling and descaling. *Crucible Steel Co.*

1823. Stainless Strip
32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, physical and mechanical properties, corrosion resistance. *Superior Steel Corp.*

1824. Stainless Tubing
New 12-page brochure on stainless steel heat exchanger and condenser tubes. Process, manufacture, chemical composition and analysis. *Republic Steel*

1825. Steel Tubing
Data Card 146-A on properties, bending, welding, heat treatment and working pressure of Croloy steel pipe and tubing. *Babcock & Wilcox*

1826. Stress-Strain Recorders
28-page bulletin No. 4215 on 16 standard recorders and 50 models of strain followers, for use on standard testing machines. *Baldwin-Lima-Hamilton*

1827. Sub-Zero Treatment
New 12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero Products*

1828. Sulphur Determination
New bulletin on high frequency combustion unit for determination of sulphur. *Lindberg Engineering*

1829. Super High Speed Steel
Folder on molybdenum, 8% cobalt high speed steel for use at speeds 20 to 25% greater than with ordinary high speed steel. Heat treatments. *Firth Sterling*

1830. Temperature Control
Facts folder on Magamp link units for proportional temperature control systems. *Westinghouse Electric*

1831. Temperature Conversions
16-page book of standard temperature conversion tables and thermocouple temperature-millivolt equivalents. *Wheelco Instruments*

1832. Temperature Indicators
Data sheet ND42-33 (1) on portable indicators for thermocouple measurements. Specifications, ranges and replacement parts. *Leeds & Northrup*

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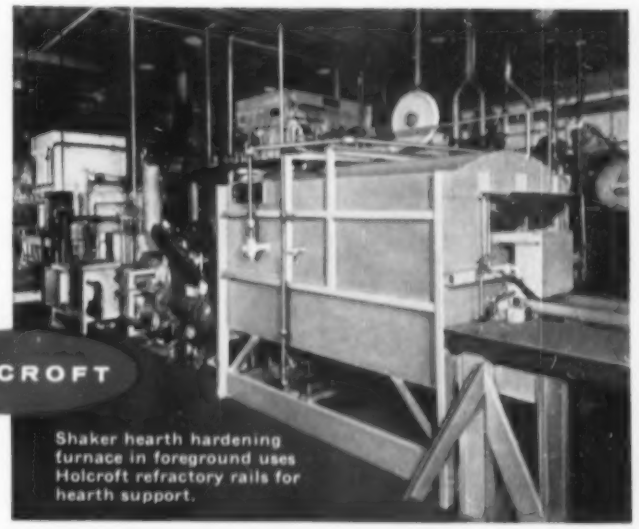

Shaker hearth hardening furnace in foreground uses Holcroft refractory rails for hearth support.

LET'S TALK ABOUT
REFRACTORY RAILS

With the current shortage of nickel, furnace manufacturers are looking for ways to replace or conserve this scarce commodity. It is interesting to note that Holcroft tackled this same problem during World War II when a nickel shortage also faced the industry.

In 1945 we designed and installed a pusher tray gas atmosphere furnace that used refractory skid rails instead of the nickel chrome alloys used at that time. Since then we have expanded their use to many other comparable applications so that now there is positive proof that properly designed installations of refractory skid rails last much longer, under similar conditions, than those made from nickel alloys. Replacements have been negligible—performance has been superior—material costs have been lower—and a marked decrease in wear on work carriers has been noted.

Yes, today a nickel shortage still exists—but Holcroft offers a job-proven answer, not only for the rails but for other vital parts of a heat treat furnace as well. You can bank on Holcroft's engineering leadership and experience—the kind that saves not only nickel—*but dollars, too!* Write for information.

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Improved production . . . improved quality of die castings are twin features of Surface Combustion's dry hearth aluminum melting furnaces. Faster production is possible with double chamber design — aluminum is melted in one chamber and held at precise pouring temperature in the other. Improved quality is the result of the accuracy of Wheelco's Series 400 Capacitrols which control the melting and holding burners. The aluminum bath is held at 1450°F with no wide swings in temperature due to the addition of cold metal.

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Specifications of new cast-to-size tensile test bar for investment cast materials. *Investment Casting Institute*

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18-page bulletin No. 168 on design of test bar patterns, production of test bars, testing procedures. *Federated Metals Div.*

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Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

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1841. Thickness Measurement

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Folder on weight slide rule for figuring weights of forgings, stock, castings and others. How slide works. *Novotni Slide Rules*

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New 52-page manual on all methods of metal joining usual to the welding shop plus metal cutting without oxygen. *All-States Welding Alloys*

1862. Welding Alloy Steel

44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

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Catalog on Cadwell process and arc-welding accessories. *Erico Products*

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32-page publication B-13 on welding rods and procedures for welding copper and copper alloys. Joint design. Table of melting point colors. *American Brass*

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Bulletin 113 on wire cloth in various alloys, in bulk or specially fabricated parts. *Cambridge Wire Cloth*

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New 4-page bulletin on X-ray diffraction for research, production control. Two units described. *General Electric, X-Ray*

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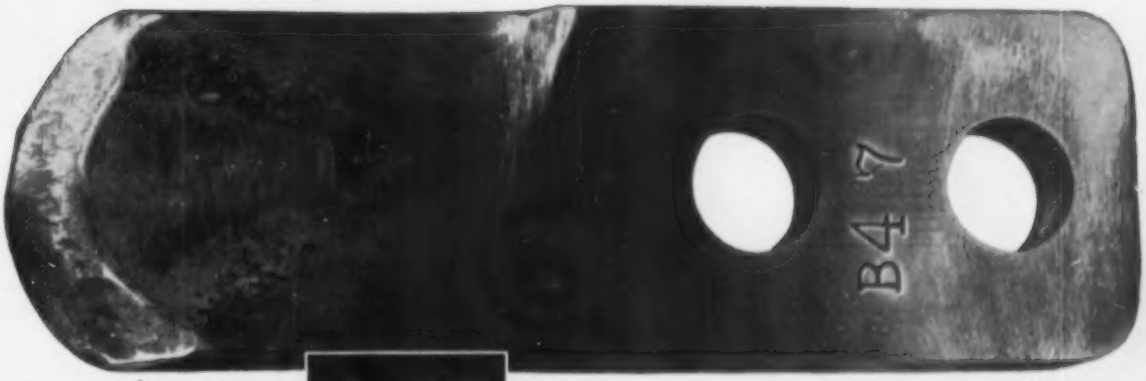

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B-47 dummy blocks, vs. 9% and 12% tungsten types, extruded more than twice as many brass and copper tubes. B-47 dies outperformed 12% tungsten type 1½ to 1.

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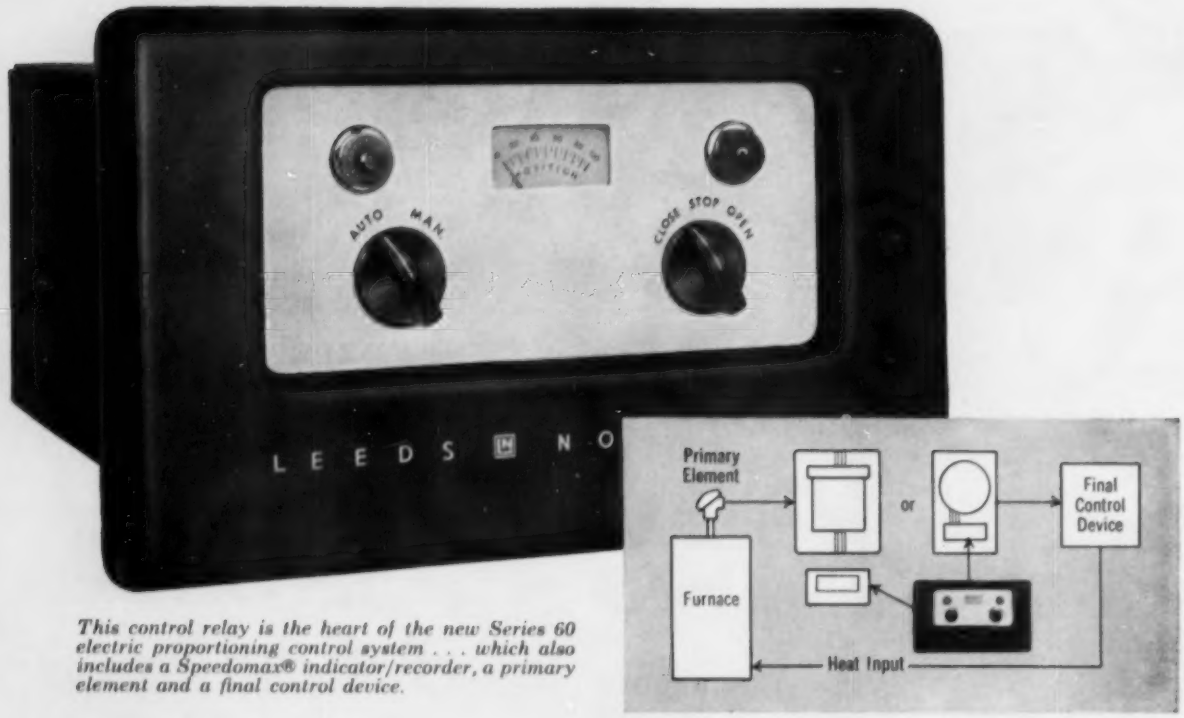

This control relay is the heart of the new Series 60 electric proportioning control system . . . which also includes a Speedomax® indicator/recorder, a primary element and a final control device.

WITH THIS NEW SERIES 60 CONTROL

You can push your furnace HARDER

■ If you're wasting valuable furnace time bringing a *batch* to temperature . . . slowing down heating rate to prevent overshoot . . . Series 60's adjustable rate of approach will bring furnace to control point smoothly—safely—in shortest possible time.

If you're losing production on your *continuous* processes due to hot spots . . . slow start-ups . . . poor combustion, Series 60's sensitivity, speed of response and control actions will provide fast, uniform heat distribution within the furnace . . . head off temperature departures as soon as they start.

Regardless of your process, if your furnace, your product and your production isn't benefiting fully from your present controls, it'll pay you to look into Series 60.

COMPLETE, FLEXIBLE SYSTEM Heart of this flexible system is L&N's new, compact Series 60 electronic proportioning control relay which receives information from the Speedomax indicator/recorder . . . immediately amplifies it and adjusts the final control device to hold temperature in line. This control relay is only 6″ x 11″ x 11″—about half the size of the Series 50 unit which it replaces. It's an integral part of our new Speedomax H instruments . . . mounts in its own case when used with Speedomax G. Expendable components—tubes, electrolytic capacitors, etc.—are plug-in for fast servicing.

VARIETY OF CONTROL ACTIONS Series 60 is available for Position-Adjusting Type (P.A.T.) or Duration-Adjusting Type (D.A.T.) control.

P.A.T. regulates input by adjusting the position of a valve; D.A.T. provides a two-position operation of the final control device . . . regulates input by adjusting the durations of heat-on time of a contactor, or of full-open time of a valve.

P.A.T. is supplied for single-action (proportional) or 3-action (proportional, reset and rate) control . . . D.A.T. for two-action (proportional and reset) or 3-action control. Proportional regulates input according to *size* . . . reset according to *duration* . . . and rate according to *speed* of temperature change. Choice of type depends upon your product, your process and your production.

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For a full description of Series 60 control, contact your nearest L&N office, or write 4927 Stenton Avenue, Philadelphia 44, Penna.

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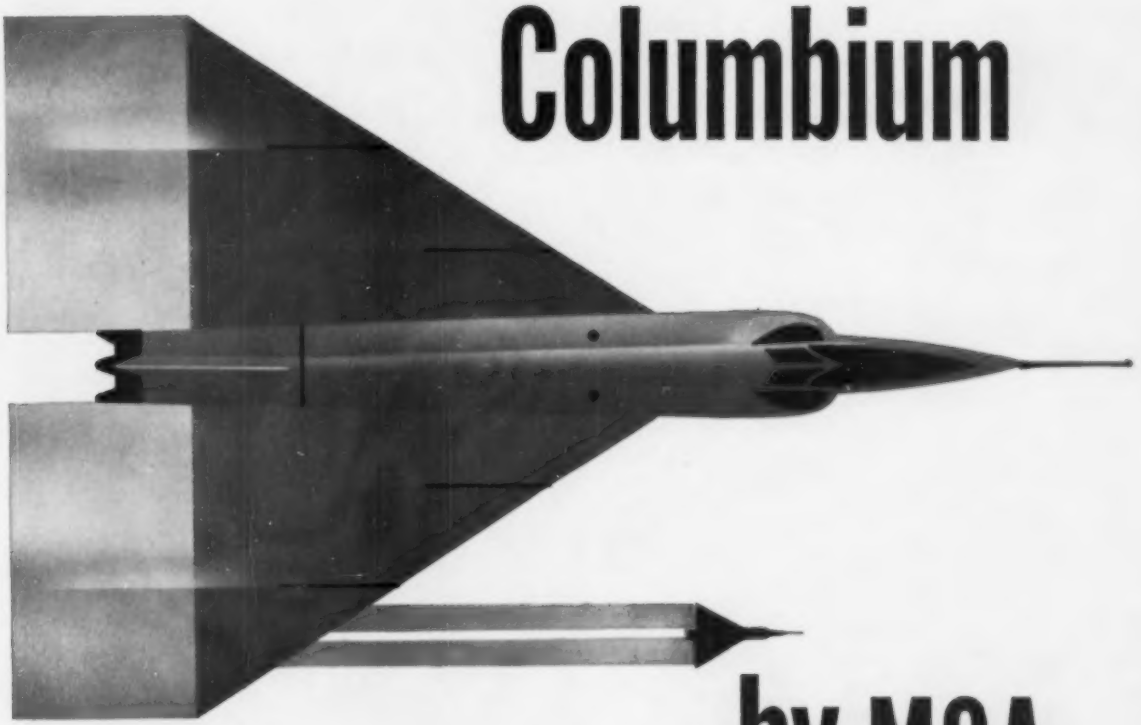

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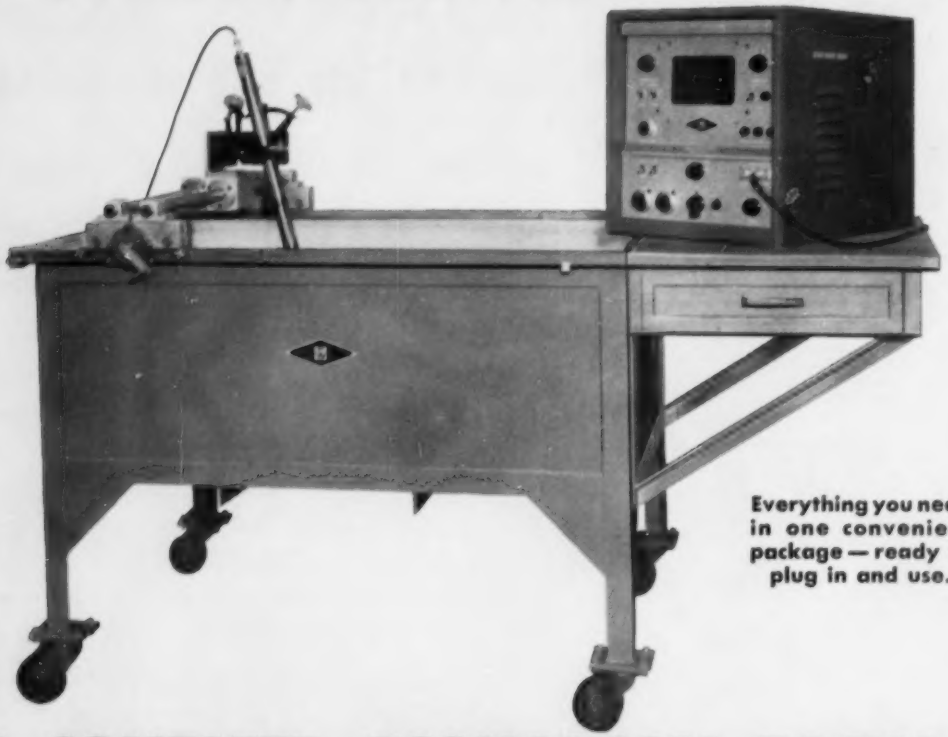

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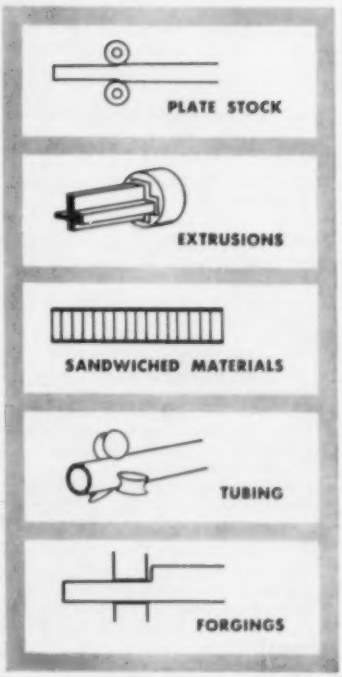

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"Techniques for Measurement of Neutron Cross Sections and Energy Spectra for Sources Which are Continuous in Energy and Time,"
Rosen, L.

"Techniques for Measuring Elastic, Non-Elastic and Transport Neutron Cross Sections,"
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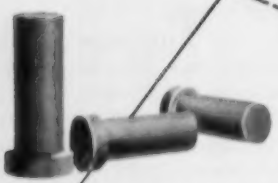

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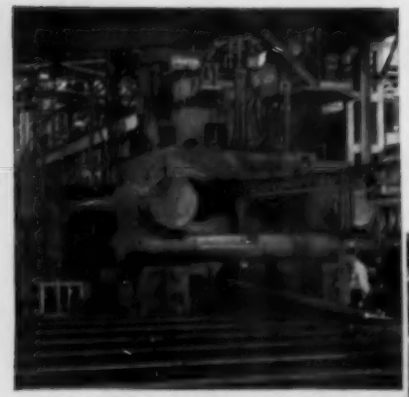

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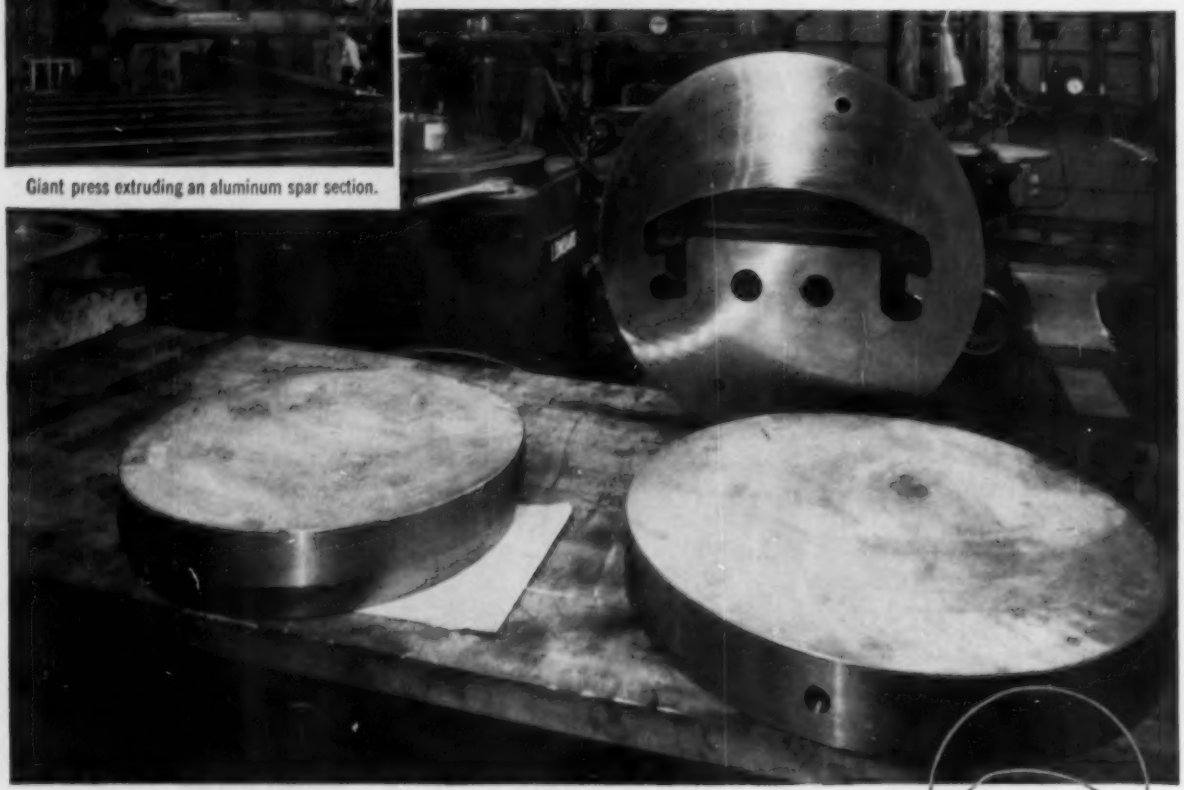

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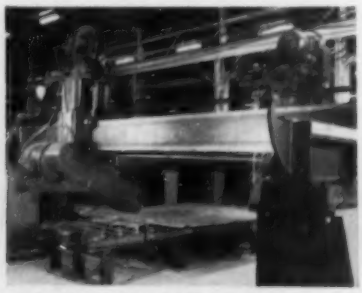

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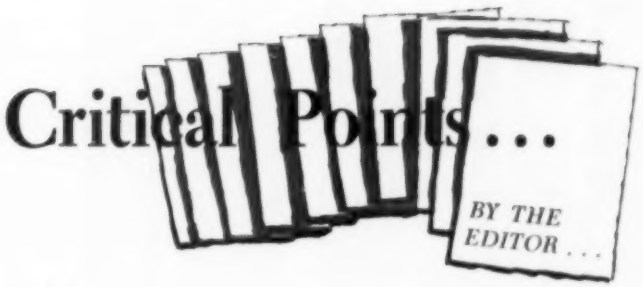
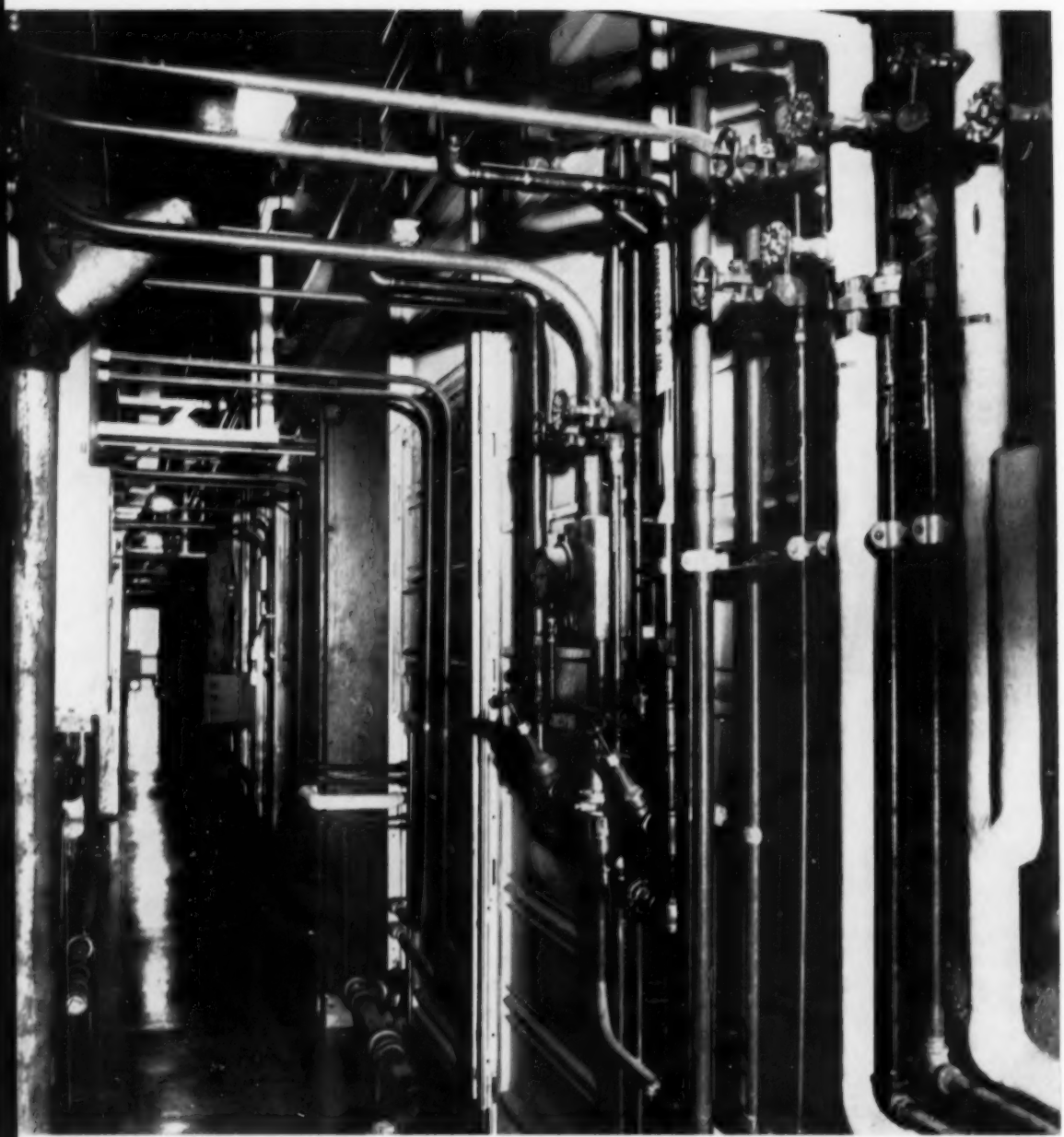


Carbons, Carbides and Hard Metals

IT IS REALLY quite in order that National Carbon Co. should build a fine, large research laboratory yet find it somewhat cramped even before it was occupied. This is in line with the long history of that company, for it was founded in 1886 by Charles F. Brush, the Cleveland inventor of the arc light, primarily to study carbon products and especially arc-light carbons. Soon it entered manufacture, and years later was one of the constituent companies of Union Carbide and Carbon Corp., when it was organized in 1917. Furthermore, practically all of the present output of this large industrial corporation, ranging from graphite electrodes to petro chemicals, calcium carbide to oxygen, and ferro-alloys to synthetics, is the product of research. None of them were even in existence 70 years ago when National Carbon Co. was formed. A third of them, undiscovered 15 years ago, now produce almost half the corporation's net income!

With Union Carbide and Carbon Corp., research is not a refinement, it is nourishment. National Carbon Co.'s new laboratory is only one of seven undergoing a $20,000,000 expansion.

The laboratory itself at Parma, an industrial suburb of Cleveland, is a handsome building of modern appearance designed by Skidmore, Owings and Merrill (the architects for the new headquarters building of the American Society for Metals, by the way). The working quarters are arranged on the module system, where the walls are movable metal partitions placed at definite intervals on the building plan. Some 158 of these units in several wings are arranged in long rows, back-to-back, separated by a 6-ft. alley which contains all the piping and conduits for the various services, each line with outlets or valves at regular intervals, so any or all of them can be installed along the walls of any laboratory at will. (This plan was first observed by the Editor in the Bell Telephone Laboratories, when it was newly erected at Murray Hill, N. J., away back in 1941.) The building is fully air conditioned; the incoming air is electrostatically cleaned and circulated only once. Hoods and



Service Alley Between Laboratory Banks

suction nozzles are especially numerous and large in capacity to prevent any carbon dust from dirtying up the premises.

Carbon is a nonmetallic element, yet is useful to metallurgists not only as a furnace material of unusual stability and as a heat producer, but also as a reducing element and an alloying element. It is interesting to physicists because ordinarily it does not melt – it sublimes or passes directly to gas except when heated to 7000° F. at pressures above 3500 atmospheres, conditions not to be expected in ordinary industrial operations. It has three forms – diamond, graphite, and just carbon (amorphous soot).

Carbon can be crystallized into graphite fairly readily by heat, but the manufacture of tiny diamonds is exceedingly difficult. The next hardest substance is far below the diamond –

boron carbide. It, together with certain other borides, silicides, carbides and nitrides, offers our best chance to make materials sometimes called "hard metals", not only of excessive hardness but also of strength and heat resistance superior to any of our 64 metals or their infinity of alloys.

As pointed out by R. G. Breckenridge, director of the Parma laboratory, the above characteristics of carbon indicate why "solid-state physics" has a major share of the research program at the new laboratory. In fact, much fundamental work in this branch of science is being done on such noncarbonaceous things as single metallic crystals, rectifiers, photo-electric cells, and solid electrolytes (dry batteries). It also warranted a conference during the dedication ceremonies on another main objective, wherein three savants laid down the principles whereby experimentation might be planned so as to have the best chance of success in finding stronger and more heat resistant solids.

"For best oxidation resistance, a silicide should produce a volatile metallic oxide and an adherent silica glass", is a simplified statement of the thesis held by Prof. Alan Searcy of the University of California, who led this discussion. He also noted it should have high thermodynamic stability. While the heat of formation is accurately known for very few of the interesting compounds it may be predicted fairly closely by theoretical methods. A third requirement is a metallic binder of high melting point which "wets" the refractory compound and reacts with it but slowly.

Applying these criteria, Professor Searcy limits hope for an oxidation resistant silicide cermet to combinations of molybdenum disilicide, silicon carbide or silicon nitride for the hard constituent, but acknowledges that there are few metallic binders which fulfill the requirements – the rare metals of the platinum group and the even rarer rhenium. Of these, combinations involving silicon carbide appear most promising. The alternative roads to success, in his opinion, are to learn how to decrease diffusion rates of the constituents through the protective silicate glass coatings, or to devise formulations which build thicker silicate coatings that will not flake off or crack when temperatures fluctuate.

The second talk on this program considered the strength of metals and the hard metallic compounds as affected by electronic binding, vacancies, grain boundaries and the like. Prof. R. Smoluchowski of Carnegie Institute of Technology showed how the recent theories of the solid state led to conclusions which were in harmony with observed facts – such as the circumstance that the strength of a material at high temperature varies directly with its grain size and is closely related to rates of diffusion. A systematic study of atomic diameters and crystalline architecture also indicated that compounds of the transition metals (scandium and lanthanum to nickel and platinum) with carbon, silicon, boron, nitrogen and oxygen would limit the profitable area of study. He also suggested that resistance to thermal shock is a prime requirement of working parts made of cermets, and while this requires low thermal expansion and high tensile strength, the most important requirement is high thermal conductivity. Professor Smoluchowski's talk left this reporter with the feeling that a tremendous amount of precise work at the atomic level would have to be done before valid predictions about cermets could be based on solid-state physics, even granting that science has set up many useful guideposts for future programs of study.

Something of this state of mind seemed to be expressed by the final speaker, Prof. Pol Duwez of California Institute of Technology, who described himself as a metallurgist. He also noted that most of the refractory hard compounds which have received attention consist of large metallic atoms and small nonmetallic atoms, and the physical metallurgists or solid-state physicists cannot agree upon the type of electronic bonding between such diverse atoms. Furthermore, since these hard crystalline compounds often do not hold to the stoichiometric ratios but exist over a range of compositions, the lattices must be full of vacancies or contain many interstitial atoms. Added to this, some macro porosity is a characteristic of powder metal products and this in itself will make it very hard to predict the properties of these complex mixtures of hard crystals bound together with ductile metal cement. Finally, their success or failure in high-temperature service will depend upon the rate of diffusion of one component into the other, and of atoms in or out through any protective surface. While the theoreticians can plot some general directions in threading this maze, Professor Duwez hopes the physicists will religiously measure the physical properties of single crystals of the likeliest constituents over the widest possible range of temperatures, and the metallurgists will go ahead in their studies in a more-or-less empirical way. Each will help the other.

Low-Temperature Brittleness

*By CHARLES S. BARRETT**

Scientific investigations of metallurgical behavior at low temperature have shown the interrelation between brittle fracture of ship plate and many of the physical properties which are determined by crystalline perfection. (Q 26, P general)

DURING WORLD WAR II our great lack of understanding of metallurgical problems at low temperatures became painfully obvious when there was a spectacular outbreak of failures of welded merchant ships and tankers. Hundreds of rapidly running brittle cracks appeared in the welded steel ships, sometimes with disastrous results. Some plates of steel which met all ordinary standards were nevertheless brittle when built into structures that were designed to operate at reasonable design-stress levels. It is now known that many structures, both riveted and welded, that had been built prior to this had suffered similar brittle failure, but it was the importance of the problem to the war effort that stimulated an intense study of it. Many important engineering and scientific studies were begun under a Board of Investigation appointed by the Secretary of the Navy in 1943. Research has continued under the auspices of the Ship Structure Committee, the Ship Steel Committee and other organizations more or less continuously since that date. As a result of the combined and coordinated effort of a great variety of research programs, more is now known about this type of failure than about any other that involves large structures.

The problem involved toughness of steel in the presence of stress raisers such as notches. In the early designs of the all-welded ships there were plenty of such stress raisers. By improvement of design in places where operating stresses were particularly intensified, there was a very marked reduction in the tendency to crack. Another design change that was effective was the breaking of the continuity of the all-welded hulls of the ships by riveting certain rows of plates to serve as crack arresters. By making these changes and by improving the quality of the welds which had contributed to the failures by providing many

*Professor, Institute for the Study of Metals, University of Chicago. This article is based on excerpts from the 1956 Edward De Mille Campbell Memorial Lecture presented before the annual meeting of the American Society for Metals held in Cleveland on Oct. 10, 1956.

built-in notches, the number of cracks 10 ft. long or longer that developed was reduced from 200 to 35 per 1000 ship-years of service in the Liberty ships. The Victory ships, which were a later design with improved details and improved fabrication practices, reached a casualty rate even lower – namely 7 per 1000 ship-years of service.

Even with perfect welds and good design there can still be notches that act as stress concentrators on a ship. They may result from handling during construction, from tack welds, from repair operations and from minor dents and impacts in service. These must be expected as a normal hazard. Since notches cannot be avoided throughout the life of the ship, it seems obvious that it is necessary to build the ship of material that is tough even in the presence of notches under conditions of service.

Tests have shown that a crack will not propagate in a brittle manner across a plate if the stress level is sufficiently low. Is it then feasible for merchant ships to be designed to a stress level so low that there is no danger of brittle fracture? If you will take the word of a man who has never designed a ship, the answer is no!

Consider, for example, the results of some tests by the Standard Oil Development Co. shown in Fig. 1. In this test, a large plate specimen under uniform tension is cooled to a uniform low temperature and then confronted with a running crack that has been started by a local impact. At any temperature below the transition from ductile to brittle behavior, about 10° F. in Fig. 1, cracks propagated across the mild steel plates used in this test at stresses of 12,000 to 13,000 psi., far below the yield strength of 40,200 psi. In other low-carbon steels, cracks propagated at stresses as low as 8000 to 11,000 psi. It is uneconomic to design large structures to such low stresses and unwise to take the risk of accidental overload in service; a better solution to the problem is to lower the transition temperature so the steel will be notch-tough at service temperatures.

The transition from ductile to brittle behavior can be measured by many different tests. The temperature of this transition varies in the different tests and frequently differs from the temperature of the transition in large structures, but tests have nevertheless been of tremendous value in developing our understanding of the problem and its possible remedies. The transition in mild steel as measured by the V-notch Charpy test is shown in Fig. 2; the upper curve indicates how the energy absorbed in breaking a specimen

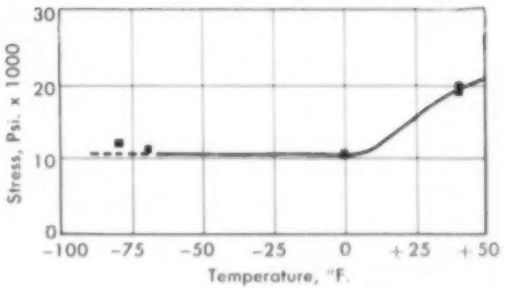


Fig. 1 – Stress Required for Crack Propagation in Mild Steel Plate

drops as temperature is lowered, and the lower curve indicates how the appearance of the fractured surface changes from the ductile fibrous fracture at high temperatures to increasing areas of transcrystalline cleavage-type fracture at lower temperatures.

An energy value is arbitrarily chosen to define the "transition temperature", for example, 15 ft-lb. in Fig. 2, or a point on the fracture appearance curve may be chosen to define a "fracture-appearance transition temperature". The latter could be at the first appearance of brittle cleavage, or when 50% of the surface is the cleavage type rather than the shear type of fracture. Let us consider the 15-ft-lb. V-notch Charpy transition temperatures that were determined at the Bureau of Standards for steel plates from World War II ships that failed. A correlation has been established between this transition temperature and behavior in service.

All plates which contained the *source* of a fracture had a transition temperature of 60° F. or higher. In every instance in which the plate at the *source* of the fracture and the plate at the *end* of the fracture for a single long crack were available, the source plate had the higher transition temperature. Because of these findings and others, it has become fairly universally accepted that improved performance results when transition temperatures are lowered.

Because of uncertainties in the relative worth of different tests, much study has been given to intercomparisons of tests and correlations of tests with service failures. The time is about here for agreement – preferably international agreement – on one or two tests to be used for most work in the future. Otherwise, unnecessary effort will be expended that could better be directed to improvement of product and to research on basic principles. It seems to some of us that there

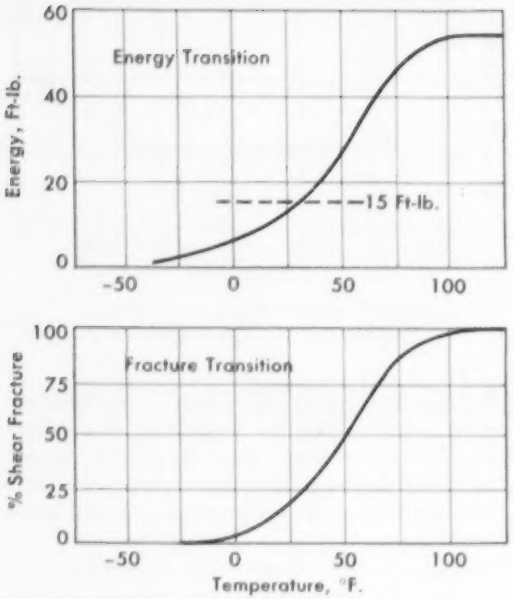


Fig. 2 — Transition From Ductile to Brittle Fracture May Be Measured by Either Impact Energy or Appearance of Fracture in Charpy Test

should be steady progress toward quality control and specifications based in some way on notch-toughness tests. This program will be hastened if world-wide service experience is made available to all and is reduced to a common standard of measure by the use of standardized test procedures.

Recently, a statistical analysis of transition temperatures in World War II ship plates and postwar plates was made with the object of determining how much lower the transition temperature should be to substantially eliminate ship failures. In Fig. 3, the distribution of transition temperatures is plotted for samples of ship plates in which the source of fractures occurred, for average plates in World War II ships and for the postwar ship steel of improved notch toughness (American Bureau of Shipping Class B, semi-killed, ¾ in. thick). Only the tail of the latter curve overlaps the source-plate curve. From this overlap and other data, statistical analysis indicates that had this A. B. S. Class B steel been used in the World War II ships, the failure rate would have been only 5% of that of the World War II steel, an even greater improvement than was obtained by improvement in design during the war. Further statistical analysis indicates that service failure should be virtually eliminated by the use of steel with a mean V-notch Charpy 15-ft-lb. transition temperature of 10° F. or lower.

Several comprehensive studies of the relationship of metallurgical variables to the transition temperature of ship steels have indicated the methods by which suitably low transition temperatures can be provided. We mention these only briefly; most of them are not applicable for economic reasons or would not be available in time of high output during an emergency.

1. Killed steel of suitable composition has very good notch toughness, but for this reason is in demand for other critical uses such as aircraft, ordnance and ship armor. The capacity for producing it is strictly limited, amounting to only about 15 million tons per year. Semikilled steel would probably have to be used in an emergency.

2. Normalizing improves notch toughness of ship plate to some extent, chiefly in the killed grades, but the normalizing capacity of this country would be completely absorbed by ordnance and other applications in an emergency.

3. Control of finishing temperature may provide substantial lowering of the transition temperature. This is a solution that is neither easy nor inexpensive but is worthy of study.

4. Adjustment and control of composition and ferrite grain size can make important changes in transition temperature. A suitable way to improve notch toughness in a given class of steel is to increase the manganese content and decrease the carbon content. By changing both carbon and manganese, the yield strength and tensile strength can be maintained. In fact, the specifications for semikilled steel have been changed this year from a carbon maximum of 0.23% down to 0.21% and the manganese range has been increased from 0.60 to 0.90% up to 0.80 to 1.10%, which should give a transition temperature near 5° F. and virtually eliminate failures.

These investigations have indicated that in large structures such as ships it is important to use plates with a transition temperature low enough to provide notch-ductility. The crack-stopping quality of plates can be controlled appreciably by composition and by production methods. Correlations of test results with service failure have established the value of tests and have indicated the compositions and steelmaking practices that can provide satisfactory performance in the various thickness ranges.

If these brief statements on ship steel toughness have conveyed the idea that the problems of toughness are all solved, they are misleading.

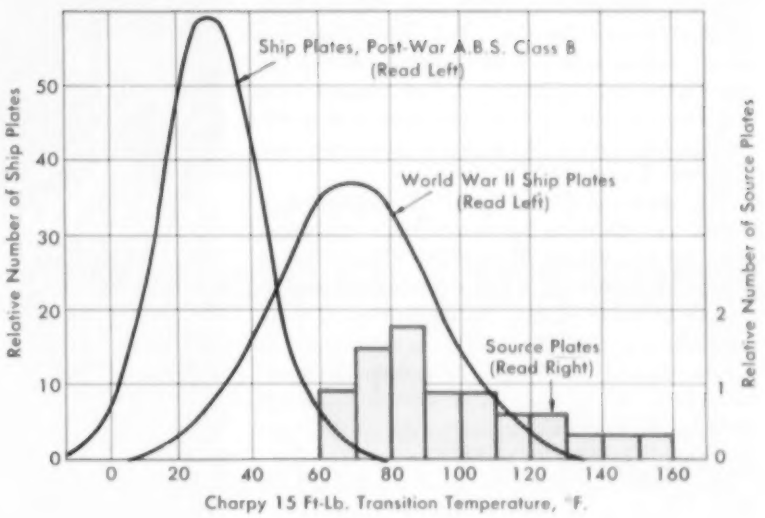


Fig. 3 – Transition Temperatures of World War II and Postwar Ship Plates. The blocks indicate the transition temperature distribution of ship plates in which brittle fracture started

Many problems remain that have to do with testing, sampling, statistics of tests and variability of properties over a plate. Additional research in the laboratory and in the mill is desirable on relationships that can lead to optimum performance at low temperatures, particularly relationships among alloy content, cooling rate, austenitizing practice, deoxidation practice, and microstructure. More should be known about factors governing the ductility of other metals that are deficient in ductility at low temperatures, such as tungsten, molybdenum, chromium, magnesium, some titanium alloys, zinc and tin. Many applications involving new uses of metals in arctic regions have increased the importance of knowing about the nature and control of the low-temperature properties of these metals.

On the fundamental side, the number of questions needing further research is very large. Only with continued progress in research, discussion and education on matters of fundamental science can the practical problems be fully understood and optimum results obtained.

The scientist interested in metals always hopes that the complexities of metal behavior will be less at low temperatures so that experiments can reveal the fundamental laws more clearly. The temperature range involved is one in which long-distance diffusion does not occur; atoms change position by making very few jumps. Imperfections in the crystalline structure have even a greater influence on properties than they do at room temperature. The effects due to specific impurities have become much better understood in recent years – in fact, in recent months.

In practice, of course, it may turn out that when we dig beneath the complexities of the high-temperature range by going to dry-ice, liquid-air, liquid-hydrogen or liquid-helium temperatures, we often uncover not simplicity but new complexities. Nevertheless, whether simple or complex, the principles established through low-temperature research are basic ones on which the whole structure of understanding of metals must rest if it is to be a sound structure.

Research on solids at low temperatures has been tremendously stimulated in recent years by the increased availability of liquefied gases in most laboratories. Liquid nitrogen and liquid oxygen can be purchased by the truckload, and in large quantities, they are about as cheap as milk; liquid helium is available "by the barrel" in many laboratories and circulating cooled helium gas is used in some. Liquid hydrogen is used freely in the larger laboratories by those who understand the associated dangers and – more briefly – by some who don't. Metal storage containers, transfer equipment, cryostats, production machinery and techniques of all kinds are now well developed and available in many laboratories. If one is fortunate, as I have been, one even finds a cooperative group of scientists in charge of the equipment who take pleasure in helping the ignorant newcomer to the field.

Some may feel that the chief characteristic of the field is uncertainty, unlimited speculation and confusion. This is normal, of course, with a rapidly developing complex area of research,

and results in discussion and critical experiments that differentiate true from false experimental conclusions and theories. But closer acquaintance in recent months with the field and with the more active investigators in it has convinced me that there is already more certainty and agreement on basic principles and interpretations than is generally realized.*

The mechanical and physical properties of metals and alloys in this temperature range can only be understood through a knowledge of crystal imperfections. The equilibrium concentration of point defects is negligible at these temperatures, but defects can be introduced in various ways: by cold work, by martensitic transformations, by bombardment with high-energy particles, or by quenching-in the defects that are in thermal equilibrium at high temperatures.

The following types of defects serve to interpret property changes in the low-temperature field: *point defects,* which are vacancies and interstitials; *line defects,* which are dislocations with or without anchoring atmospheres; *surface defects,* including arrays of dislocations acting in unison, and thin microcracks; and *volume defects,* in which class we might put displacement spikes and rounded cavities.

From a great number of studies, investigators have related specific defects to certain properties of metals with at least moderate confidence. The point defects, when present in excess numbers in metals and alloys, increase the electrical resistance, specific volume, rate of local diffusion, rate of local ordering and rate of precipitation. The point defects interacting with dislocations produce increased elastic constants, decreased internal friction, yield points (in body-centered cubic alloys), delayed yielding and under certain conditions, a large temperature dependence of yield stress. Dislocation arrays at martensite interfaces produce martensitic phase changes when they move, and this movement may be impeded by the presence of other defects (cold work stabilization). Displacement spikes influence the density, elastic constants, and perhaps also the yield and flow stress and their temperature dependency.

*Editor's Note: The complete Campbell Lecture, to be published in full in Vol. 49 of the *Transactions*, includes several sections reviewing recent low-temperature researches dealing with the fields of mechanical metallurgy, transformations, phase diagrams at low temperatures, and changes in properties induced in metals by bombardment with high-energy particles. The role of crystal imperfections in each field is pointed out.

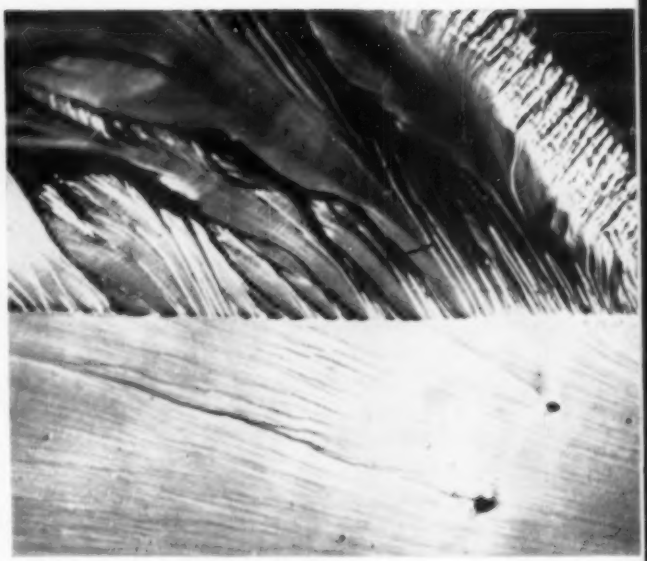


Fig. 4 – A Low-Angle Boundary in 3% Silicon-Iron Containing Screw Dislocations

No one set of defects is responsible for low-temperature brittleness of metals, for this is related to the presence of anchoring atmospheres, to dislocation arrays that produce stress concentrations and possibly, in some instances, to microcracks – all are factors that raise local stresses on cleavage planes. The interrelation between brittleness and virtually all other physical properties of metals which are being studied at extremely low temperatures has contributed much to our understanding of solid-state physics but much more research is necessary. A good example is the rapidly developing and, at the same time, the most puzzling subject in low-temperature metallurgy – the effects of high-energy radiation on metals. Irradiation by neutrons, electrons or other nuclear particles causes atoms to be knocked out of their lattice positions and creates various lattice defects. Practical metals engineers prefer to leave the study of such defects to the research scientist because they are considered of only theoretical importance. Unfortunately, irradiation of a pressure-vessel steel with 2.5×10^{19} neutrons per sq.cm. raises its transition temperature from -22 to 122° F. While there are very few parts of a nuclear power plant that are hit by anywhere near this amount of radiation, it is obvious that any steel and other materials used near the core of a reactor must be chosen with this radiation-embrittlement danger kept closely in mind.

Some Effects of Lubricants in Cold Rolling Thin Strip

*By J. C. WHETZEL, Jr. and CHARLES WYLE**

The maximum reduction of thin strip can be increased from approximately 12 to 62% at the same rolling speed by changing the lubricant. (F 1, CN)

IN COLD ROLLING STRIP, particularly at high speeds, the exterior surface of the rolls and the stock is flooded with a cooling or lubricating medium. It is necessary on some special jobs to cold roll without lubrication but the amount of heat liberated by the deformation of the metal makes it difficult to maintain accurate gage without adequate cooling.

Rolling mill operators recognize the need for cooling but frequently ignore some of the other advantages which may be realized with special kinds of lubricants. These include:

1. Greater reduction per pass.
2. Lower power requirements for a given reduction.
3. Thinner strip obtainable with a specific roll diameter.
4. Better control of dimensions and surface finish.
5. Less waste heat generated.
6. Elimination of the necessity for regreasing prior to annealing.

Some of these lubricant properties are more important than others for any specific application. Careful choice of the proper rolling lubricant can improve most rolling operations, particularly those on thin strip.

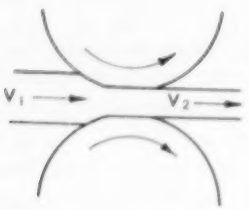
The external friction generated between the stock and the rolls makes it possible to deform the metal. This same friction also limits the amount of deformation possible. Because the strip is moving faster when leaving the rolls than upon entering, there must be slippage between the stock and the rolls which is opposed by friction. The greater this opposing friction, the greater the roll-separating force and power required to deform the stock. Since the greater separating force causes increased roll flattening, the length of the arc of contact becomes greater, thus requiring a higher separating force and greater power. The roll flattening effect, while seldom trivial, is particularly important in

*Mr. Whetzel is with Allegheny Refining Co., Verona, Pa. and Mr. Wyle is in the engineering department of the Fenn Manufacturing Co., Newington, Conn.

the rolling of thin, hard stock. For example, the length of the contact arc may increase as much as 150% in rolling tin plate. On very thin stock, the increased length of contact due to roll flattening increases frictional force so substantially that the stock is literally locked in the rolls and cannot be deformed. The gage at which no further reduction can occur is determined by the diameter and mechanical properties of the rolls, the metal being rolled, strip tension and the coefficient of friction.

The equations and methods used to calculate maximum reduction of cold rolled strip are discussed in detail in another article to be published by the authors.

While some experimental work has been done to evaluate the coefficient of friction at various speeds and with a number of lubricants, the data available today are still incomplete. It has been found to vary inversely with rolling speed in large five-stand tin-plate mills. In current tin-plate rolling practice, operators compensate for its higher value and the resultant greater stock thickness at lower rolling speeds by increasing the strip tension between stands, thereby permitting the metal to be reduced to the desired thickness.



Friction Develops in Rolling Because of Slippage Resulting From Difference in Entry and Exit Speeds of the Strip

Lubricant Test Program

It should be more economical to control the coefficient of friction by proper selection of lubricant and rolling speeds than to compensate for it. Fenn Manufacturing Co. and Allegheny Refining Co., as producers of rolling equipment and lubricants, respectively, are cooperating in a joint effort to determine how to control friction in rolling. The specific goal is to learn how to adjust rolling speed and lubricant composition to obtain the maximum reduction of thin strip with a specific mill.

The mill used is a Fenn heavy-duty precision rolling mill. The rolls are 7½ in. in diameter by 8 in. The speed of the 25-hp. drive motor can be accurately controlled over the range from 0 to 1000 ft. per min. The strip is coiled on a low-inertia, adjustable-tension, adjustable-speed take-up reel with speed correction for coil build-up. This mill had been modified as follows:

1. Compression springs, for the purpose of maintaining approximately constant roll-separating force for small variations in strip thickness with no further mill adjustment, were placed between the mill adjusting screws and upper bearing boxes.

2. A strip oiler had been provided which was simply a modification of the rolling mill entry guides.

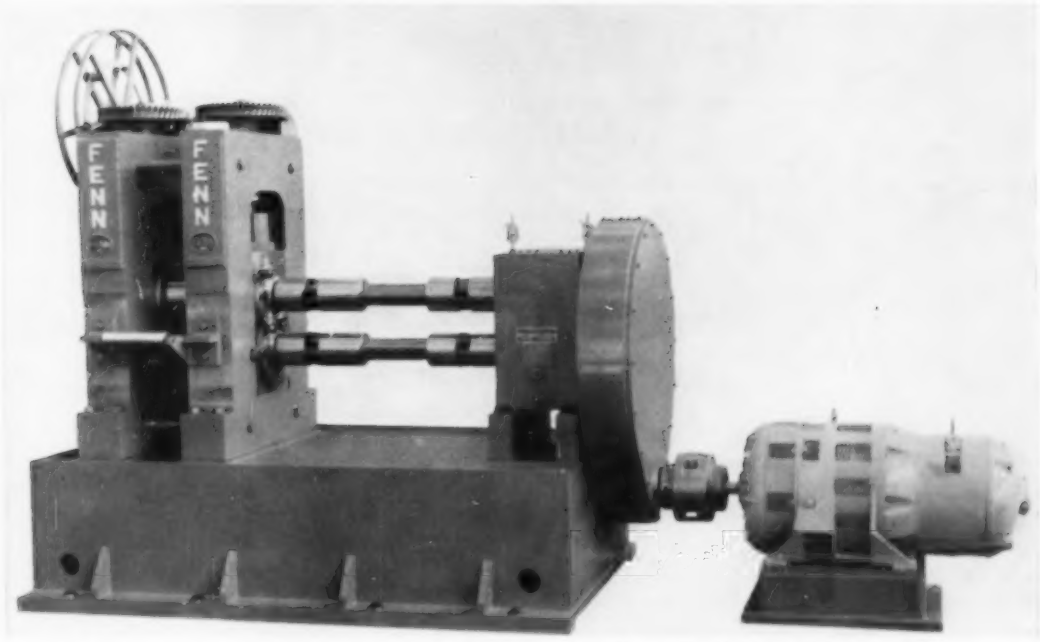
3. A small stream of lubricant from a reservoir was forced by compressed air into the entry guides to form a puddle through which the strip passed.

4. Metal "squeegees" were placed at the exit of the guides, just ahead of the rolls, to permit only the proper amount of lubricant to be carried to the rolls.

The strip was marked as it left the mill to record the rolling speed of the particular section. The simple marking device consisted of a silver alloy wire actuated by a solenoid, a capacitor and a rectifier. The wire tapped the strip 200 times a minute which caused a small arc to leave a silver "dot" on the strip at each tap. The rolling speed, in feet per minute, was determined by multiplying the distance between any two consecutive dots by 200.

The material studied was cold rolled S.A.E. 1010 slit strip, 0.0063 × 0.251 in. and 0.0063 × 1.001 in., with a tensile strength of 91,000 psi. and elongation of 0.5%. In addition, some tests were run with fully annealed Type 302 stainless steel, 0.0055 × 0.250 in., with 93,000 psi. tensile strength and 40.0% elongation. It is evident that the thickness of this material is very near the lower limit of gage ordinarily obtainable with 7½-in. diameter rolls. At this ratio of strip thickness to roll diameter, almost no reduction will occur with dry rolls regardless of pressure, and small changes in lubricant efficiency will produce large changes in reduction.

A separate length of strip, approximately 125 ft. long, was used for each test run. The stock was threaded through the mill entry guides and oiler, passed between the rolls past the speed marking device and attached to the take-up reel. With



Fenn No. 081 Two-High Strip Mill Used for Evaluation of Lubricants

the lubricant flowing into the oiler-guides and the marker in operation, the mill was started and the rolling speed increased uniformly to 1000 ft. per min. within a 10-sec. period. Upon completion of the test run, the strip on the take-up drum was uncoiled and examined along its entire length for thickness variation, width variation, spacing of the silver "dots" and surface finish. All equipment was cleaned thoroughly between runs to eliminate all traces of the previous test lubricant. It should be noted that the mill adjusting screws were left at one setting throughout a series of runs in which the same strip was used with different lubricants.

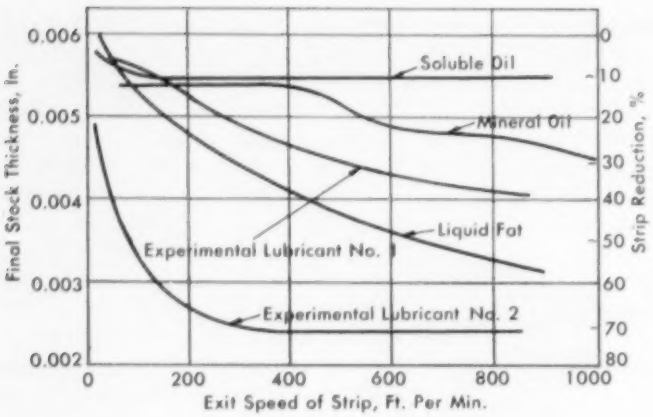
Test Results

The strip thickness varies in almost direct proportion to the coefficient of friction, the figure that expresses the performance of the lubricant. The comparative values obtained could have been replaced by actual values of coefficients of friction if the roll-separating force had been known. However, no suitable means of measurement was available at the time of the runs.

With a conventional "soluble oil" lubricant, simply an emulsion of oil in water, the amount of reduction of the 1010 strip increased with rolling speed to about 13% at 150 ft. per min. and then remained constant with increase in rolling speed to 1000 ft. per min. The surface was flat and shiny and the lateral spread of the 0.251-in. width was 0.012 in.

A number of different mineral oils were tested and with most of these, the strip failed as rolling speed was increased. One uncompounded mineral oil with Saybolt universal viscosity of 300 sec. at 100° F. could be used over the entire range studied. The amount of reduction was about constant at 15% for speeds up to 350 ft. per min. and then increased with increase of rolling speed to about 28% at 650 ft. per min. The percent reduction was constant from 650 to 1000 ft. per. min. The surface of the strip was flat and dull at low speeds and warped at high speeds. The lateral spread was 0.018 in.

The lubricant usually used on high-speed cold mills producing tin plate is a liquid fat which permits reductions that vary inversely with speed. The reduction ranged from about 12% at 100 ft. per min. to 50% at 1000 ft. per min. The same lubricant was used in a special run without springs in the mill and reduction again increased with speed up to about 250 ft. per min. and then remained constant at 16%. Apparently, as the reduction increased the roll-separating force decreased and prevented further deformation. The



Effect of Lubricant and Rolling Speed on Cold Reduction

surface produced with the liquid fat was flat and fairly shiny and the lateral spread was 0.013 in.

An experimental water-soluble lubricant was developed which would burn off with no residue in an annealing furnace and which could be rinsed off completely with cold water. A flat and very shiny surface was produced but the maximum reduction was not as great as with the liquid fat. At 1000 ft. per min. the reduction was about 38%.

A modification of this water-soluble lubricant was tried and the amount of reduction increased to over 70% at speeds under 200 ft. per min. Unfortunately, the strip broke at about 220 ft. per min. The rolling load was reduced for another run with this lubricant and again the reduction increased rapidly to about 62% at 350 ft. per min. and remained constant at speeds up to about 850 ft. per min. The lateral spread was only 0.007 in. at low speed and 0.004 in. at high speed. The surface was flat with a soft matte finish and the lubricant could be rinsed off completely with water.

Additional runs were made using the wider strip, 0.0063 × 1.001 in., slit from the same coil, and the results appeared to be essentially the same. Lateral spread was in the range of 0.007 to 0.004 in., identical to the run on narrow strip. Evidently, spread is not a function of width. Finally, all springs were removed from the mill so that maximum force could be applied. The mill was tightened to give maximum reduction and rolling was continued with the same wide strip and lubricant. Maximum reduction was not readily reproducible, but was approximately 70%. Additional tightening of the mill had no apparent effect on minimum thickness. The calculated value of coefficient of friction was 0.04.

The stainless steel strip behaved like the carbon steel although the maximum reduction was not as great. With the modified water-soluble lubricant, the reduction increased to about 58% at 250 ft. per min. and then remained constant at higher rolling speeds. A greater load and stiffer springs were required for the stainless. The surface was flat with a soft matte finish. The lateral spread was 0.009 to 0.011 in. at low speeds and 0.008 in. at the high speeds.

Discussion and Summary

It is obvious that lubrication of the stock affects the amount of reduction obtained at any given rolling pressure. In this instance, where the ratio of strip thickness to roll diameter was 0.00084, the effect of improved lubricants was very pronounced with reductions ranging from a low of 12.7% to a high of 62% at 600 ft. per min. The authors expect this difference to be much less pronounced in a less difficult case of rolling — that is, where the ratio of strip thickness to roll diameter is greater. Nevertheless, a considerable amount of rolling is done in difficult ranges and the trend to thinner strip is becoming more evident. Therefore, it is of great practical and economic value to develop lubricants that will permit rolling to very thin gages.

It was expected that gage would decrease as speed of rolling increased since this phenomenon has been recorded often in both literature and practice. The variation in the behavior with changes in the type of lubricant was unexpected and is of much interest. It appears that it may be possible to develop rolling lubricants that would minimize speed effects and reduce the operating problems associated with the accelerations and decelerations of mills.

Book Review...

European Report on American Die-Casting Practice

*By DONALD L. COLWELL**

ZINC AND LIGHT METAL DIE CASTING, European Productivity Agency of the Organization for European Economic Cooperation, Paris, France, 1955, 149 p., $2.

This report is an excellent review of American practice in die casting prepared by Tecaid Mission No. 155 which visited the United States in 1954 under the auspices of the Organization for European Economic Cooperation and the American Foreign Operations Administration. The Tecaid team was divided into four sections which toured the northeastern area of the country but did not necessarily visit the same plants. The plants studied included producers of die castings, die builders, machine builders, alloy producers, testing laboratories and plating plants.

The team members were fully aware that this very efficient method of mass production was particularly adapted to American industry where quantities of products using die castings are normally many times the production of the corresponding items in Europe. No mention was made, however, of the fact that the opportunity exists for equivalent volume of such products in Europe if the political questions of different currencies, export control and customs barriers could be eliminated.

With the large variation in American die-casting machines, it is not surprising that the section devoted to their description is not complete. The discussion of dies is valuable and well-done with excellent information concerning die materials and hardening practices. The comment that American practice lays more emphasis on metal savers and thin walls is a corollary to the larger production quantities where greater die expense is less important. The statement that dies are generously proportioned, however, is unfortunately not always true, as all connected with the industry have seen examples of dies which were made too light to withstand the service of the casting machine.

The section on metallurgy is up-to-date and accurate, even though the observations were made two years ago. For example, the evaluation of Zamak 3 being much more widely used than Zamak 5 is accurate, as well as is mention of the trend toward the higher zinc content allowable in the aluminum-base alloys. Although No. 384 is listed, it is not mentioned as an alternate for No. 13 whereas it often is preferable to No. 360. The comment that an alloy used several times was better for die casting than a virgin alloy is also worthy of note.

The chapter on foundry practice was certainly representative of our better die-casting practice. While the mission observed only hot metal being charged to the holding pots of cold-chamber machines, the charging of ingot and scrap into these holding pots is all too prevalent. The discussion of the various die lubricants used indicated emphasis on the art rather than the science, although it concludes with the same remark that in producing hardware-finish zinc die castings, little or no lubricant is advisable.

The chapter on finishing is a description of practice in finishing automotive hardware, and as such, represents the highest quality requirement and the largest volume of production. The production and finishing of die castings for automobiles is an excellent example of the automation possible with volume production.

The section on management and labor is particularly interesting since it brings out a fundamental difference between labor-manage-

*Director of Laboratories, Apex Smelting Co., Cleveland.

ment relations as practiced here and abroad. The mission seemed particularly interested in the fact that production problems are often solved by labor and management working together harmoniously.

There are 4½ pages of recommendations made to industry as a result of the tour, and many of these seem too elementary to an American die caster. For example, "An adequate number of ejector pins should be provided" seems almost as elementary as to say that a die should be built. On the other hand, many of these recommendations, such as that on keeping the use of lubricants to a minimum, the feeding of holding pots with molten metal rather than ingot and the wholehearted endorsement of the zinc die-casting certification plan, could well be taken to heart by American industry.

In closing, it should be remarked that the criticisms mentioned above are very minor compared to the excellent discussion of the over-all die-casting industry given in the report. The writer has taken part in a number of similar exchanges of information and this is one of the best that has been published. It is recommended even to those currently "skilled in the art".

The Safe Operation of Atmosphere Furnaces

*By J. HUEBLER**

Some atmospheres used in industrial furnaces can explode if carelessly managed. The best preventive is adequate training of operating personnel. (J 2, A 7)

MANY of the controlled atmospheres used in industrial furnaces are combustible and under special conditions may explode or detonate. Such explosions may damage equipment and present a threat to the safety of operating personnel. Because accidents have been relatively rare, insufficient attention is paid in the literature to the latent danger inherent in the operation of atmosphere furnaces. Accidents have occurred just often enough to emphasize that operations must be conducted with a pious regard to safety procedures, and such procedures must be carefully analyzed in advance to care for all exigencies which may come up in emergencies.

Few installations can ever be planned which are totally and completely safe under all conditions of emergency. Even if they were, cost-conscious operators would not always allow a safety system to go through a complete cycle if it cut into the production rate.

There must of necessity be a difference of interest between the manufacturer of furnace equipment and the operator. The furnace manufacturer must sell furnaces in competition and therefore cannot be expected to include every conceivable piece of safety equipment calculated to meet any emergency. The operating company

*Surface Combustion Corp., Toledo, Ohio. Paper for A.S.M.-Industrial Heating Equipment Association Meeting at National Metal Congress, Cleveland, Oct. 9, 1956. Read by Norman Davies, chairman of the I.H.E.A. Safety Committee. Assistance and contributions by other members of the Industrial Heating Equipment Association are gratefully acknowledged.

requires a certain level of production from the furnace. If for the sake of enhancing his production, the operator sometimes closes an eye during an operation which has certain dangers, he justifies it on the basis that it works. Only in the event that there is an "accident" does he carefully appraise all of the procedures; then it is too late.

Certainly there can never be a complete substitute for properly instructed operating personnel whose reactions to emergency situations have been carefully planned and practiced. Safety equipment has its great value in alerting the operators and giving them the necessary time to secure the equipment manually in a specific emergency. Consequently the combination of alert operating personnel and a certain minimum of safety gear is the best and most commonly employed means of assuring safe and trouble-free furnace operation.

In the final analysis, the best possible safety aid is the *good* operator – and there is no substitute for him.

Although most of this discussion is concerned with methods of avoiding explosions, a few words should be added here about the possibilities of carbon monoxide poisoning. Most of the atmosphere gases contain lethal percentages of carbon monoxide. Proper attention must be given to adequate ventilation and to combusting the atmosphere gas as it escapes from the furnace or generator vent. In addition, all personnel working in the furnace area should be thoroughly alerted to the danger of breathing unburned atmosphere gas.

Throughout this paper the word "furnace" refers both to the heated and unheated zones, as well as vestibules.

The Basic Explosion Problem

The training of a furnace operator must include an understanding of the conditions under which an explosion can occur.

It is well known that certain mixtures of combustible gas and air will burn when ignited. When such a mixture is ignited in a confined space, it will burn rapidly enough to create a large change in temperature in a short time. The pressure in the confined space will rise very rapidly. This rapid rise in pressure may cause almost instantaneous rupture of the container confining the original mixture. If there are openings in the container, high-velocity streams of intensely hot gases may be projected out of the container even if it is strong enough to resist rupture. Without going into any great technical detail, the events described above generally characterize an explosion.

In order for an explosion to occur, there must be a mixture of combustible gas and air capable of burning rapidly, the mixture must be present in a confined space and finally, it must be ignited.

A knowledge of the limits of mixtures which are capable of combustion and the limits of ignition temperature is therefore basic to understanding the conditions which are potentially dangerous in operation of prepared atmosphere furnaces. Although there might be a controversy about the exact limits of ignition temperature, and clearly a "cold" spark is capable of igniting a variety of cold mixtures, the limits given below are generally accepted for the purpose of safety discussion procedures.

Explosive mixture limits are usually defined on the basis of mixtures which are capable of propagating flame throughout the system from a single point of ignition. If the mixture is deficient in flammable gas (lower limit) or so deficient in air (upper limit) that it cannot propagate a flame through the confined static mixture, the mixture is said to be nonexplosive. It should be appreciated that a mixture too rich to be explosive (beyond the upper limit) if allowed to admix with more air will become an explosive mixture before it passes to the lower limit of explosion.

Some furnace atmospheres contain so small a percentage of combustible gas that they are nonexplosive and remain nonexplosive when air is added in any amount. Atmospheres of this type are called inert atmospheres.

In prepared atmospheres for industrial furnaces, the inert or safe atmosphere gas has been variously defined as a gas containing less than 8.8%[1], 6%[2] or 4%[3] total combustibles. In such atmospheres, the combustibles consist of approximately equal parts of hydrogen and carbon monoxide with little or no methane. The first two limits were established by work done by the Bureau of Mines[4]. The highest value considers the mixture to be at room temperature, the intermediate value takes into account the fact that the mixture may be preheated to 900 to 1000° F. before ignition, while the lowest value is a practical figure which credits the elevated temperature of the mixture and provides for some margin of error in operation. For safety purposes the lower values are preferred.

While the ignition temperatures of these gases are listed[5] as low as 1000° F. and as high as 1200° F., ignition at these temperatures may be

delayed. When positive ignition is desired, the minimum temperature that is considered safe is 1400° F.[1]

In addition to the danger of fire, burns and secondary effect of fragments, the result of an explosion can be destruction of the equipment due to the pressure generated by the explosion within the furnace. For example, a perfect mixture of endothermic gas used for carburizing will attain a temperature of about 3100° F. when burned. This will theoretically raise the pressure within the furnace, if not relieved, to over 80 psi. gage. Most furnaces are not built to withstand such pressure and would be blown apart. Even a 10% combustible gas perfectly admixed with air can produce a pressure of 25 psi. gage.

To sum up the foregoing, whenever an atmosphere gas contains more than about 4% combustibles, great care must be taken in its use to avoid the possibility of forming an explosive mixture of the atmosphere gas and air within a furnace.

Purging

In the following text, repeated reference is made to the operation of purging in connection with the safe handling of furnaces below 1400° F. Although this process is generally well understood, a few words on it may be helpful.

The purging process may be illustrated by following the important occurrences during the purging of the air from a cold furnace zone with an inert atmosphere gas prior to the introduction of a flammable atmosphere. As the inert atmosphere enters the furnace, it mixes with the air in the furnace and this mixture issues from the furnace effluents. As the addition of inert gas continues, the mixture within the furnace contains a smaller and smaller fraction of air. In most circumstances, it is found that when the volume of inert purge gas used is equal to five times the total furnace volume, analysis of the gas in the furnace will show no residual oxygen and purging is considered complete. It is important to distinguish between purging by continuous admixture and purging by displacement which would only require one furnace volume replacement with purge gas. The latter method is not used very often for industrial furnaces.

Although the above statement that five volume changes will complete a purge is generally true, the operator should not rely on this but should always analyze the mixture within the furnace to prove that the purge is complete.

Types of Operation and Safety Implications

Most furnaces may be divided into:

1. Those in which the entire furnace is above 1400° F.
2. Those in which part of the furnace is above 1400° F. but any cooler zones are short and not divided from the hot zone by doors.
3. Those in which part of the furnace is above 1400° F. but with a long or separated cold zone.
4. Those in which furnaces are entirely below 1400° F.

Furnaces which are entirely above 1400° F. are relatively safe. When the flammable atmosphere is put in, the gas ignites immediately and positively, burning with the air in the furnace. Thus it is not possible to form a combustible mixture which can explode. To remove the atmosphere, air is allowed to enter and burn with the flammable atmosphere.

Furnaces which are partly above 1400° F. and which have short cold zones not divided from the hot zones by walls or doors normally will not be able to accumulate explosive mixtures. In this type of furnace, the atmosphere must be added only in the hot zone where ignition is positive. The flue gases formed by the burning atmosphere must sweep out and purge the cold zones. It is essential in this instance that the hot zone be large enough in relation to the cold zone to provide sufficient flue gas to purge the cold zone. To remove the atmosphere, air must be added to the hot zone and the flue gases so formed must be caused to purge the cold zone or zones.

Furnaces in which part of the furnace is above 1400° F. but with long or separated cold zones can be very hazardous since it is easy to build up an explosive mixture within the furnace. A special example of this type of furnace is one in which all parts are above 1400° F. except for vestibules at the charge and discharge ends. In normal circumstances, these furnaces can be started up and shut down with relative ease because the outer vestibule doors can be opened and the normal small volume burned out even though the vestibules are cold.

Furnaces with long cooling zones present a special problem. In such installations, the hot zone is not of sufficient size to provide enough flue gas to purge the cold zone adequately. Many equipment manufacturers recommend an auxiliary source of inert purge gas for this application, although very expert and careful operators

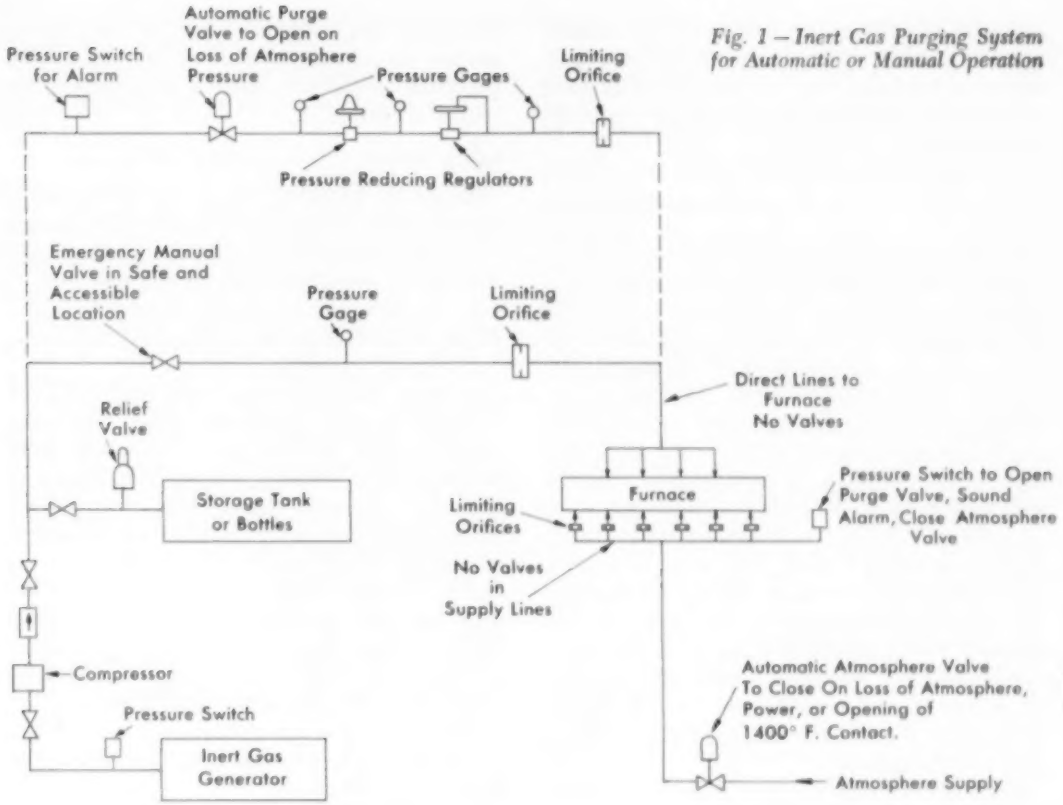

Automatic Purge Valve to Open on Loss of Atmosphere Pressure
Pressure Switch for Alarm
Pressure Gages
Limiting Orifice
Pressure Reducing Regulators
Emergency Manual Valve in Safe and Accessible Location
Pressure Gage
Limiting Orifice
Direct Lines to Furnace No Valves
Relief Valve
Storage Tank or Bottles
Furnace
Pressure Switch to Open Purge Valve, Sound Alarm, Close Atmosphere Valve
Limiting Orifices
No Valves in Supply Lines
Compressor
Pressure Switch
Inert Gas Generator
Automatic Atmosphere Valve To Close On Loss of Atmosphere, Power, or Opening of 1400° F. Contact.
Atmosphere Supply

Fig. 1 — Inert Gas Purging System for Automatic or Manual Operation

can introduce the atmosphere by burning in and remove the atmosphere by burning out if very special procedures are adhered to. A schematic representation of an inert gas production and storage system which can be operated automatically or manually is shown in Fig. 1.

Furnaces which are entirely below 1400° F. present a problem similar to those with long cooling zones and therefore the same general rules apply.

The batch-type furnace which must be placed under atmosphere or degassed while cold is a special problem of wide interest. The most common practice with such equipment is to purge with the flammable gas when starting cold and with air at the end of the cooling cycle with the provision that no ignition source can be purposely or accidentally applied during the purge period.

Emergency Precautions

The preceding discussion has assumed normal operating conditions. However important the precautions during normal operating conditions are, the emergency conditions caused by the failure of power, fuel, air and sometimes water, or the failure or malfunction of the atmosphere generator itself are usually of even more concern.

When such failures occur, they call for quick and expert action by competent furnace operators as well as proper functioning of reliable safety aids which have been placed on the equipment with careful forethought.

When the power, fuel or air fails, the atmosphere gas supply and the furnace heat supply will both be lost. Cooling begins immediately, causing a contraction of the gas volume within the furnace. This contraction causes air to be drawn into the furnace which may quickly convert the atmosphere within the furnace into an explosive mixture. Consequently, a very dangerous situation may develop within a very short time. If the furnace is open-ended, air begins to diffuse into the furnace as soon as the atmosphere supply stops, even if the temperature remains constant. The process may be extremely rapid. Because these events occur rapidly, it is essential that the operators be well schooled in their reactions to emergencies.

If a failure of a utility occurs, the furnace user is normally advised to burn out the flammable atmosphere immediately, if the burn-out

procedure is safe for that furnace. With furnaces operating below 1400° F. or with extensive cooling zones the hazards of burning out are so great that standby storage of inert purge gas is usually recommended.

In carburizing and similar applications where the furnaces carry very valuable work loads, it is common to find the furnace user supplying natural gas to the furnace as a substitute atmosphere. Then if failure of the atmosphere gas occurs, the natural gas is manually turned into the furnace as a substitute atmosphere. In an emergency, an operator can turn the natural gas into a furnace very quickly. The procedure, therefore, not only can save the work load in the event of shutdowns of short duration, but also has the advantage of permitting an operator sufficient time to introduce natural gas to a number of furnaces and subsequently secure them in an orderly manner. The above procedure is not dangerous providing that the furnace has not cooled below 1400° F. However, if the operator waits for resumption of the failed utility before burning out the furnace and thereby allows the furnace to cool below 1400° F. before burning out, the situation is seriously out of hand and very dangerous.

Some of the more common protective systems and preventive methods are listed in Table I[6], and the types of emergencies for which the systems and methods have been designed.

It is possible for atmosphere generators to malfunction under very special circumstances. When they do, they may deliver air, gas, premix or other off-analysis atmospheres. This possibility can be prevented only by frequent careful maintenance and by hourly or continuous analysis of the atmosphere gas. In view of the serious consequences of such an atmosphere generator malfunction, there is no substitute for proper attention.

Table I — Prevention of Explosions of Furnace Atmospheres During Emergencies

	Emergency Interruption		
	Power	Fuel Gas	Atmosphere
Protective systems			
Inert gas storage	X	X	X
Bottled inert gas	X	X	X
Steam purging system	X	X	X
Preventive methods			
Motor generator	X		
Manifolded generator			X
Natural gas*	X		X
Bottled LP fuel gas		X	

*Natural gas may be used only when the temperature of the furnace is above 1400° F., but in electric furnaces it may damage the heating elements.

Safety Aids

Generally speaking, many of the common safety aids are mechanical devices which provide a time interval for the operator to take the proper steps in an emergency. Aids of this type are:

1. Switches which are responsive to pressure, failure of air, fuel gas, atmosphere gas and water.
2. Flame protection devices.
3. High and low-temperature limit contacts.

These devices generally cause automatic valves to close. Electric power failure will cause the same thing. Usually, it is recommended that after the automatic valves close, the operator immediately close all manual valves associated with them. This is particularly necessary on the fuel gas supply valve. There have been many instances where such automatic valves have been found to leak slowly so that perhaps minutes or even hours after an emergency shutdown an explosion resulted because of such leakage.

The following is a list of safety aids which are in common use on atmosphere generators, and their normal functions:

1. Fuel gas pressure switch. Closes fuel gas valve and stops air blower, gas booster or mixing pump.
2. Air pressure switch. Closes fuel gas valve and stops air blower, gas booster or mixing pump.
3. Water pressure switch. Closes fuel gas valve and stops air blower, gas booster or mixing pump.
4. Normally closed safety valves. Closes fuel gas valve on power failure.
5. Flame supervising devices on exothermic generators. Closes fuel gas valve and stops air blower, gas booster or mixing pump if burner is extinguished.
6. High-temperature limit on endothermic generators. Closes fuel gas valve and stops air blower in event generator becomes overheated so as to prevent damage to generator.
7. Low-temperature limit on endothermic generators. Closes fuel gas valve and stops air blower, gas booster or mixing pump if generator becomes too cold in order to prevent the delivery of off-analysis gas.
8. Flowmeter gages on air and fuel gas to generator. Allows a trained operator to estimate at a glance if generator is operating normally.
9. Fire check in premix line to generator.

Prevents damaging backfire to mixing pumps or remote mixing station.

The following is a list of safety aids which are in common use on atmosphere furnaces, and their functions:

1. Atmosphere pressure or flow switch. Shuts off atmosphere valve if atmosphere supply fails.
2. Manual reset valve. Shuts off atmosphere to furnace if atmosphere pressure or power valve fails. Requires manual reopening by operator on resumption of service.
3. Automatic closing and reopening valve. Same as manual reset valve except that it automatically reopens on resumption of utility.
4. 1400° F. contact on furnace temperature instrument. Does not allow automatic valves on atmosphere supply to be opened until furnace is heated above 1400° F. Closes valves if furnace drops below 1400° F. (See discussion below.)
5. Flowmeter gages on atmosphere supply to furnace. Allows trained operator to estimate if atmosphere flow to furnace is normal.

All of the above devices are usually connected to visible and audible alarm devices to alert the operator to the fact that there is an emergency.

In connection with the use of items in the above list, there are some areas of disagreement. One disagreement involves the use of automatic reopening and manual reset valves. From one standpoint, the automatic reopening valve is preferred in the event of momentary power losses. This is by far the most common emergency condition and if the atmosphere supply is not lost, the reopening valves allow the operation to continue without loss of production or sacrifice of safety. On the other hand, in the event of longer delays, the operator may forget to close the manual valves and a dangerous condition will result when the valve automatically reopens. Which of the above is the better procedure depends upon the reliability, training and competence of the furnace operators.

A second area of disagreement concerns the use of the 1400° F. contacts. There has been considerable objection to the use of this contact for closing off the atmosphere supply. The contention is that the interests of safety are better served if the atmosphere is allowed to continue to flow and maintain furnace pressure. In such instances the switch merely sounds an alarm to alert the operator and he can correct the situation in an orderly and safe manner.

There may be other devices which can be used as safety aids. For example, continuous gas analyzing devices are getting some recognition. Such instruments can be used with automatic shutoff valves and alarms and give a continuous record of the atmosphere suitability. Their drawback has been the complicated maintenance required to insure continuous operation.

Safety Responsibility

The final responsibility for the safe operation of atmosphere furnaces and generators rests with the equipment user. His decisions, however, should be guided by his insurance underwriter and his equipment supplier.

The equipment manufacturer must be familiar with the safety requirements of insurance underwriters so that his design will conform as far as possible. The equipment manufacturer must make every effort to point out to the user all potential operating hazards which might exist or develop as well as the possible methods to overcome the difficulties. He must impress upon the user the need for adequate maintenance and competent furnace operators and he should issue complete and clear operating instructions for the furnace and auxiliary equipment.

The furnace user's major responsibility is to insure that the equipment is maintained in perfect working order and to provide completely competent well-educated operators. Some companies are developing check list methods for both maintenance and operation as an aid in this direction. The furnace user must also be familiar with insurance requirements and be certain that all safety equipment desired is provided in the proposed furnace as well as complete operating instructions.

Additional information on the subject of the safe handling of atmosphere gases is contained in "Protective Atmospheres", by A. G. Hotchkiss and H. M. Webber, published in 1953 by John Wiley & Son.

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Preservation of Stored War Materiel

*By J. L. McCLOUD**

A recent conference organized by the Navy's CB's shows that the favored method of protecting against corrosion is to store under tight cover within which is circulated an atmosphere of controlled humidity. Vapor-phase inhibitors and contact preservatives are also being used to an increasing extent. (R 10)

IT WILL DOUBTLESS BE news to most readers of *Metal Progress* that the U.S. Department of Defense owns as much as 100 billion dollars worth of equipment – half of it being in storage – and that this inventory is increasing at the rate of 15 billion per year. This includes everything from ships, vehicles, tanks, artillery, aircraft and their repair parts, down to uniforms, small arms ammunition, electron tubes and forks.

Obviously, its preservation against the time it will be used is a major problem, worthy of a conference recently called by the Naval Construction Battalion Center at Port Hueneme, Calif. The name Hueneme (pronounced Y-Ne-Me) is of Indian origin and means Resting Place. While it was the military problem that sparked the meeting, it was also of major interest to industry – although industrial storage is seldom for the length of time often endured by the military.

Some 200 specialists attended discussions on military requirements, costs, preservative research, metal coatings research and controlled humidity research. Many speakers pointed up the fact that a disheartenlingly great amount of materiel which left the factories in first-class shape was ruined by the time it got to the theaters of use; that while all concerned now have a far better conception of the ever-present damage from tropical climates, there is still much to learn about the optimum conditions for preservation; that "lead time" in a third World War will be practically zero – the war will most probably be fought with available weapons, ammunition and materiel; and that while it's very well to have stores, we don't want to find out that they are either obsolete or that they have deteriorated to uselessness by corrosion, mildew, or slow chemical change.

During World War II the shipments of materiel to the various theaters of war clearly and sadly showed the need for better methods of preparation. At the end of the war and again after the Korean action, the need to store all the vast Army, Navy, Air Force and Marine items in better condition was re-emphasized. With ready-time and demand reduced now to hours, new solutions must be found for these problems.

The problem is so large it is not surprising to find that there is no unanimous view, no agreement on the proper approach. For a simple (?) example, take automotive vehicles and earth-moving equipment in dead storage.

The Marine Corps uses one approach to this storage and maintenance-for-use problem. Marines keep the line ready by exercising the equipment on a regular periodic schedule and by a liberal use of preservative lubricants which are left in place. But such periodic exercising isn't

*Consulting Editor, *Metal Progress*.

acceptable by other branches of the armed forces. Some find it too expensive and inefficient. The Army, for example, has many specifications on docking, storage, and preservatives which must be followed by anyone concerned.

Since corrosion is the most destructive force and since corrosion is caused by incompatible climate – heat, moisture, sunlight, ozone, airborne acids and salts – the job is to keep the wrong elements out of the wrong places. Simply said, but not so simply done! Packaging for shipment or storage has been improved over the years but still has plenty of room for further improvement.

Controlled humidity is considered the most promising solution nowadays – even steel-hull craft are dynamically dehumidified. Stores, especially static ones under cover, can have the air circulated over solid beds to remove moisture. (Cyclic inspections may be made and are also important.) Typical of the difficulties and shortcomings of storage depots is the limitations of coverings. At Port Hueneme the CB's are planning dehumidified warehouses and already have these on test comparing them to uncontrolled storage in sheds and outdoor locations. In the dehumidified warehouse, infiltration creates the greatest load on the ventilating machinery. Transmission of moisture through floors and walls is quite high. However, in some climates ventilation is not only possible but desirable and designs must provide for this.

One novel approach to atmospheres with controlled humidity is to use air-supported hutments. These are made of polyethelene membrane, 0.004 in. thick, so light that the pressure only of the air from the dehumidifying machines will keep them inflated. They can be quickly built and provided even with walk-in doors. Being under positive pressure, they aren't subjected to air infiltration other than that purposely provided. They are being used over stores of materiel and even over machines and lines of machines set up in shops ready to operate. They have the further advantage of low cost.

Another method, borrowed from European practice, is to use natural caves or worked-out mines for storage places. These give very good results at low cost, provided ground water does not seep into them. They can also be used for machine tools or vehicles. On ships the hulls themselves, of steel, can be the envelope. Gun enclosures of steel sheet have been found better than the built-up plastic shells.

Earth-moving equipment is quite similar to other automotive vehicles except that perhaps more high-alloy steel may be used. In this connection the advantages of "VPI" (vapor-phase inhibitors) were described; they protect during storage, and on reactivation no cleanup is required for immediate use. One of the Naval Air Stations is highly enthusiastic over the results. Comparison with contact preservatives using sulphonates, acid neutralizing amines plus a petroleum wax to give a thixotropic film is favorable. Volatile intermediates in combination with aerosol dispersants put the corrosion inhibitors into difficultly accessable places with obvious advantage.

In the search for better methods that combine both lubrication and protection, the fluorinated hydrocarbons such as "Teflon" and "Kel F" may provide some answers.

Nor is this a study by the armed forces alone. Representatives from the steel, chemical and rubber industries all told of their work and accomplishments. For example, very thin vinyl coatings can be used on steel before fabrication and the sheet may then be formed and subsequently finished with excellent corrosion resistance. These operations naturally must be controlled and monitored, and a method to detect corrosive atmosphere with a thin film of iron and glass or plastic was described.

Program and Training – Stock rotation of stores is of value not only to forestall obsolescence but to detect damage and permit retreatment for preservation. To be sure, all these methods and devices are not without some objections but an accounting still leaves the balance in favor of careful preparation.

Proper design and provision for these goals will not be sufficient. Training is required for workers and supervisors alike.

It is evident that the armed forces are hard at work perfecting methods and materials for protection of equipment in storage, and have already advanced to a gratifying extent. To be sure, much that they are doing is a natural extension of former operations. The materials for protection are those they and industry use regularly. Dehumidified air is a natural development of the use of dessicants in packaged goods. Carrying it to a whole area and into caves is a natural sequence.

The use of vapor-phase and vapor corrosion inhibitors is a continuation of industrial developments. One comment is that it might be more widely used – a matter which will be emphasized in a later article in *Metal Progress*.

Biographical Dictionary of

Norman Luther Mochel
Manager of Metallurgical Engineering
and Consulting Engineer
Westinghouse Electric Corp.

Eminent Living Metallurgists

THE LIFE OF Norman Mochel is probably one of the closest approximations to the Horatio Alger story to be found in modern times. One of a family of six children whose father earned a modest living as a decorative plasterer in Pittsburgh, young Norman was offered only one opportunity to go to college. Unfortunately this involved an obligation to study for the ministry, and this boy's interests lay in material things – the holes in his pants pockets, according to his family, resulted from the chunks of scrap metal he collected and cherished, as his contemporaries cherished their marbles and tops.

So in 1912 at the age of 16, Norman went to work in the engineering department of the Westinghouse Machine Co. Eventually he rounded out his practical education with some night school courses; he is now a registered professional engineer licensed in Pennsylvania to practice metallurgical engineering, and is an honorary member of Pi Tau Sigma, national honorary mechanical engineering fraternity.

After two months doing clerical work at Westinghouse, young Mochel was transferred to the inspection department. For the next eight years he made the most of his associations with Westinghouse personnel, which included some of the great engineers of the era. His personal contact with George Westinghouse came through Mochel's work on the famed "Neptune geared turbine".

His greatest inspiration however was probably J. B. Thomas, chief inspector and a man of remarkable abilities, who took a kindly interest in this ambitious and promising lad, and taught him all he could from his vast knowledge of practical mechanics. With Albert Kingsbury, Mochel worked on thrust bearings; William A. Bole, general manager, awakened his interest in the heat treatment of steel; others whom Mochel remembers with grateful heart for their advice and encouragement are E. S. McClelland, superintendent, Francis Hodgkinson, chief engineer of the machine company and later of the Philadelphia Works, and H. T. Herr, vice-president.

After a year's interruption for military service during World War I (master engineer with duties in road building and maintenance, quarries, maps and administration), Mochel returned to the machine works of Westinghouse Electric & Mfg. Co. in East Pittsburgh. This plant was being moved to South Philadelphia, and for a year he commuted between the two cities, merging the practice of the old machine company into the specifications system of the new parent company. In July 1920 he settled permanently in the east, becoming metallurgical engineer for the South Philadelphia Works. The steps in his career are marked by subsequent changes in title – division engineer, metallurgical division; manager of metallurgical engineering, steam division; and now, since 1944, manager of metallurgical engineering and consulting engineer.

At Westinghouse Mochel's metallurgical activities and interests have been as broad as the company's list of products is long and varied. In his consulting and trouble-shooting capacity for the company he has helped the transformer division in the welding of large shells; the transportation and generator division in the manufacture of large rotor forgings, furnaces, processing of sheet metal; in the rolling mills, supervising steel manufacturing problems; in the X-ray division, the industrial applications of X-ray apparatus; at the Sunnyvale plant, the manufacture of wind tunnel forgings and welding problems; in the aviation gas turbine division, as general consultant; in the atomic power division, an active member of the consulting committee.

When Mochel moved east in 1920 it was a double event, for he brought his bride, the former Ruth Bond of Pittsburgh, with him. They settled in Ridley Park, Pa., where their home is still located. The Mochels have two fine sons, John and Gordon, both engineering graduates of Swarthmore. John is in the mechanical engineering department of the Philadelphia Electric Co. Gordon is a mechanical engineer with Ingersoll-Rand Co. at Phillipsburg, N. J., and has completed the scholastic work toward his Master's degree at the University of Pennsylvania.

With all of his duties at Westinghouse, Mochel has managed to participate in an amazing number of those extracurricular activities that

broaden a man's horizon and enhance his value to the profession.

He joined the American Society for Metals way back when it was the Steel Treaters Research Society in Detroit (1917) and served as chairman of the Philadelphia Chapter in 1932-33. In 1937 he presented the Sauveur Lecture before the Philadelphia Chapter, and is a member of the A.S.M. Advisory Committee to the Temple University Research Institute. In 1948 he was voted a distinguished service award on the occasion of A.S.M.'s salute to the seventy-fifth anniversary of alloy steel.

In the American Society for Testing Materials, however, Norman Mochel has found the greatest outlet for his talents. After two terms on the board of directors (1935-37 and 1949-52) he was elected national vice-president and subsequently president in 1954. He currently serves on five separate A.S.T.M. committees and was chairman of Committee A-1 on Steel for 14 years from 1939 to 1953. At various times he has served as secretary of other committees, as chairman of the Philadelphia District Council, and chairman of the Standing Committee on Standards.

One of the oldest members of the Joint A.S.T.M.-A.S.M.E. Research Committee on Effect of Temperature on the Properties of Metals, he has put in time and effort as secretary, vice-chairman, chairman for five full terms, and chairman of various subcommittees and panels. He is now chairman of the Finance Committee.

Among his many significant honors the A.S.T.M. has awarded him the Charles B. Dudley Gold Medal for a paper jointly with P. R. Toolin on "The High-Temperature Fatigue Strength of Several Gas Turbine Alloys". He also presented the first H. W. Gillett Memorial Lecture for the A.S.T.M. in 1952.

A complete listing of all of his technical society and committee activities would make pretty dull reading; typical are chairman of a panel on pipe standards for high temperatures for the American Bureau of Shipping, chairman of a subcommittee on high-temperature pipe advisory to the Bureau of Ships; consumer member of the Specifications Committee of the Steel Founders Society of America; member of the Advisory Committee on Metallurgy to Drexel Institute of Technology; member of the Metallurgical Advisory Committee of the Bureau of Standards.

Honors have been equally widespread, and in addition to those already mentioned include the Westinghouse Silver-W (a joint award with his associates), the Gold Medal of the Institute of Naval Architects, a special Gold Medal of the Institute of Marine Engineers, and a Lincoln Arc Welding Foundation Certificate of Award.

Just this year he presented the annual Mehl Honor Lecture of the Society for Nondestructive Testing on "Standards for Nondestructive Testing Practice".

He is a member of the Committee on Arts and Sciences of the Franklin Institute. This impressive list of activities would be most incomplete without some mention of the various ways he has served the United States Government, both in war and in peace. His World War I service has already been mentioned; during World War II he served on a project committee of the War Metallurgy Committee, and as a member of the Five-Man Administrative Committee of the National Emergency Steel Specification Project. For the National Advisory Committee for Aeronautics he served on the Subcommittee on Heat Resisting Materials from 1944 to 1950, including a two-year period as chairman. For the Office of Naval Research he served as a member of the Research Advisory Group on Gas Turbine Material Development from 1945 to 1948.

He is currently a member of the A.S.T.M. Ordnance Advisory Committee, was metals representative on the Industrial Advisory Committee to the Munitions Board, Government Catalog Plan; and served on the Panel on Power for Propulsion of the Underseas Warfare Committee of the National Research Council.

This seemingly endless list of accomplishments could be still further amplified by citing the titles of numerous published papers, book contributions and lectures before technical societies and universities, including a wartime stint as a welding instructor at Temple University.

One would think that such a man would have little time for any interests beyond those of his profession, yet Mochel has managed to pay serious attention to his civic and community duties. These include membership on the Ridley Park School Board for 7½ years, the post of chairman of civil defense from 1940 to 1945, and for almost 20 years general superintendent of his Presbyterian Church school.

Such a career can be nothing but a tribute to the American spirit of enterprise and service. Such a spirit was innate in the young man who had few formal opportunities presented to him yet has learned where to find them and how to shoulder responsibilities — to the great benefit of his profession and his community.

Conservation of Nickel in Electroplating

*By V. L. McENALLY, JR. and F. G. BRUNE**

At least one third of the nickel used in electroplating would be saved if deposits of uniform thickness could be obtained. Some techniques for improving uniformity are described. (L 17, Ni)

FOR OUTDOOR PROTECTION of decorative parts made of low-alloy steel, a minimum thickness of nickel plate of 0.001 to 0.0015 in. is required. Because of the poor throwing power of nickel plating solutions, the coating produced is nonuniformly distributed on production parts. This means that we use from 1½ to 3 lb. of nickel for each pound of nickel that would be required if we could plate the part uniformly. About 62 million pounds of nickel will have been used by electroplaters in 1956 and at least one-third of it expended because of poor distribution.

While it is true that the design of many contour parts causes most of the variation in the thickness of nickel plate, the use of designs pleasing to the eye is also responsible for the increased use of nickel plating. Development of methods that improve distribution will also improve quality; any resultant increase in plating cost would undoubtedly be justified by the attendant conservation of nickel.

The problem of nonuniform nickel plating has been studied by the authors for about 20 years and a number of techniques have been developed to conserve nickel. The two most important factors found to influence variable plating thickness are current distribution due to the contour of the part plated (cathode) and the distance between anode and cathode.

A clear understanding of the effect of cathode shape on the distribution of the current is essential, since the amount of nickel plate in a given area is a result of the amount of current passing through that area. The term "primary current distribution" is used to describe the amount of current that will flow through the different areas of the cathode. What actually happens is that electric current prefers to flow through a point or edge. Therefore, the amount of current flow is greatest at parts of greatest curvature. The curvature of a sharp point or edge approaches infinity so at such areas the rate of current flow becomes very great and we call it a high-current-density area or point. It means that current flow from a shape will react similarly to the way electrostatic electricity would distribute on shapes, as shown in Fig. 1. This principle of current flow accounts for a number of common observations:

1. Thick plating on a point in a recessed area.
2. The increased rate of growth at a burr, sharp point or "tree".
3. Heavy polish lines and gouges showing up worse after plating.
4. The use of knife edge hangers and contactors.

The distribution of current flow is not constant for a given shape but varies with the rate of current flowing. The greater the amperage, the

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Fig. 1 -- Distribution of Electrostatic Charge Around Sphere and Egg-Shaped Object Indicates How Shape Affects Electroplate Thickness

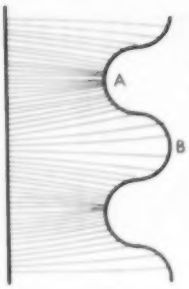


Fig. 2 – Current Flow Density Between Flat Anode and Corrugated Cathode

more the current flows from the high-current-density areas and the poorer is the distribution. Theoretically, the ratio of current between the high- and low-density area is a constant but in practice a change of ratio occurs due to polarization and other effects, so we call it "secondary current distribution".

A practical measurement of current distribution can be made by checking the significant areas of a part. The ratio of maximum to minimum thickness is in direct proportion to that of the current distribution. For well-designed parts, this ratio should be four or less. The plating thickness is fairly uniform on circular or spherical parts but on a flat strip, the thickness at the edge will be approximately 3.9 times the thickness at the center. An S-shaped corrugated section with generous radii will be plated about four times thicker in the areas closest to the anode than in the base of the recessed areas. The root of sharp recessed angles may have as little as 5% of the plating thickness found on high-current-density areas of the same part.

In addition to the cathode shape, the distance between anode and cathode also affects the variation in plate thickness. The factors are additive; that is, the closer a high-current-density point is moved toward the anode, the greater is the percentage current flow and the more nickel is deposited on that point. The effect of anode-to-cathode distance is directly proportional to ratio of maximum to minimum distance between cathode and anode. For example, if point *B* in Fig. 2 is twice as far from the anode as point *A*, only half as much nickel will be deposited at point *B* because of the effect of distance only.

It is obvious that increasing the distance between anode and cathode will decrease some of the variation in plating thickness. For example, if a part with a 6-in. deep recess when plated with a minimum anode-to-cathode distance of 6 in. is plated four times as heavy in the areas closest to the anode as in the root of the recess, part of the difference is due to the shape factor and the rest to the distance. Since the distance to the root of the recess is twice the minimum anode-to-cathode distance, the distance factor alone causes the heavily plated areas to be twice as thick as the minimum thickness areas. In other words, if the minimum thickness in the recess is 0.001 in., the maximum thickness at the surface is 0.004 in.; 0.002 in. of this is due to the shape factor and 0.002 in. to the distance factor. To reduce the variation due to distance, it is necessary to move the cathode away from the anode. If the minimum anode-to-cathode distance is increased from 6 to 18 in., the distance factor is reduced from 2 to 1.33 $(24 \div 18)$ so that the ratio between maximum and minimum plate thickness is reduced from 4 to 3.33. An increase of 36 in. would decrease the distance factor to 1.17 $(42 \div 36)$ and the ratio between maximum and minimum thickness to 3.17.

With properly designed parts and equipment, the major factor that then controls uniformity of plate thickness is the distribution of the current due to the part shape. A number of methods of changing the current distribution are used in commercial plating to decrease variation in plate thickness. One method uses a conductor placed near the cathode at a high-density area so that some of the current is used to deposit nickel on the conductor. This is a wasteful process used only for lack of a better method, since the conductor, called a "robber", takes metal that would normally go on the part. In special instances, nickel wire or shapes can be used and the metal reclaimed. Where nickel is the only coating applied, some salvage value of the nickel on any robber material is usually obtained. However, when a robber gets multiple coatings of copper and nickel, little can be salvaged.

Placement of a nonconductor or insulated shield between the anode and cathode as in Fig. 3 forces the current to flow around the shield. This decreases the plate thickness at the normal high point and improves the general distribution.

It has a number of disadvantages:

1. Increased cost of the rack fixtures.
2. Increased cost to maintain the rack fixture.
3. Possible increased cost for labor to rack and unrack the part.
4. Drag-over and rinsing problems in the plating cycle.

Both anode-to-cathode distance and the current distribution due to shape cause similar types of changes in the plate thickness distribution. By reversing their effects upon a part, improved

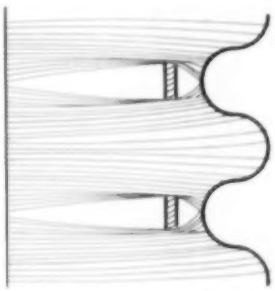
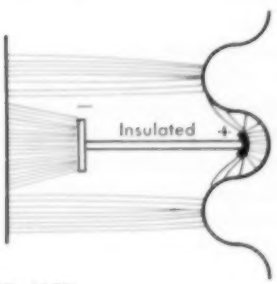


Fig. 3 – Insulating Shields Decrease the Current Flow in High-Density Areas and Improve Plate Uniformity

thickness distribution can be obtained. Current distribution is determined by the shape of the cathode but it is possible to use a shaped anode so that the anode-to-cathode distance is a minimum at the low-current areas and a maximum at high-current areas, and thus improve plate distribution. Usually, instead of a shaped anode, an insert anode is used to increase the thickness at low-current-density areas. With larger parts, this can sometimes be accomplished by merely hanging anodes only in positions opposite the low-current areas.

A special method for decreasing the anode-to-cathode distance is illustrated in Fig. 4. A conductor is placed between the anode and cathode to increase the amount of current flowing to a recessed area, and acts as a dipolar anode. The two faces of the dipole and the connection rod between must have good electrical conductivity. The rod or wire connecting the two pole faces must be insulated. Because the metal conductor has less resistance than the solution, current flows through the dipole to the recessed areas.

Fig. 4 – Bipolar Anodes Increase Current Flow to Recessed Areas

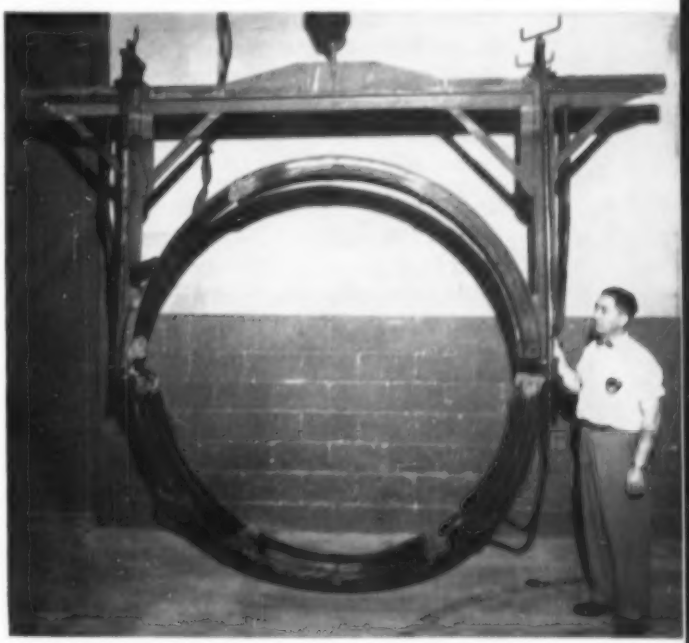


If the shape of a part permits an anode to be placed so that it is equidistant or nearly so from all points on the cathode, uniform plate thickness distribution will be obtained. In place of a center anode, a nonconducting shield with a narrow opening properly located can be utilized between the anode and cathode to achieve the same effect.

Current distribution and its effect on thickness on a flat panel are fairly well determined and can be listed for a panel plated on both sides in terms of the amount of nickel deposited in each section of the panel.

Section of Panel	Weight of Nickel
Central 40%	30%
Next 40%	37
Next 10%	13
Edge 10%	20
	100

Fig. 5 – Rack With an Insulating Shield to Protect the Edges of a Large Surface and Prevent Excessive Deposit



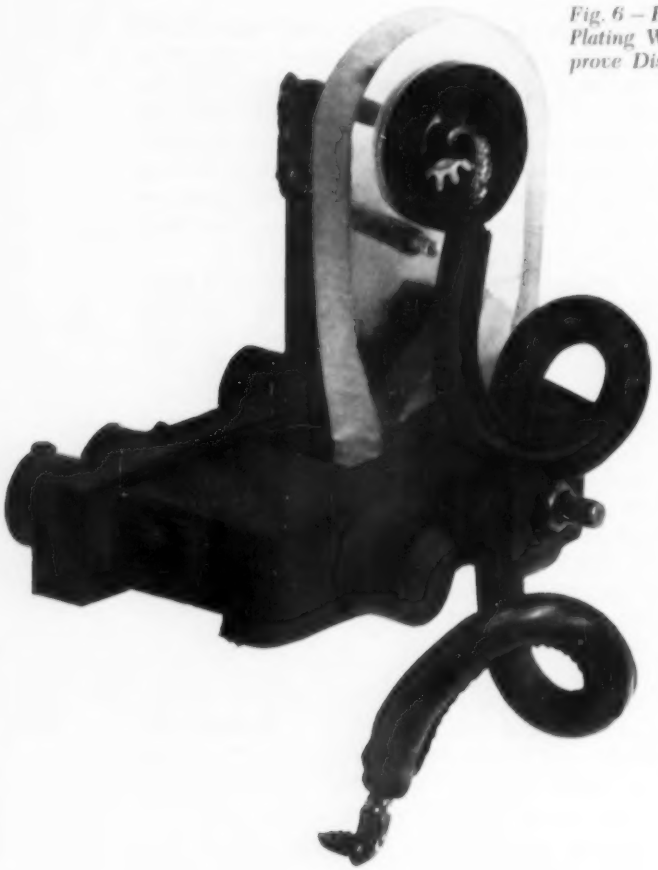


Fig. 6 – Rack Showing Mask to Prevent Plating With a Central Anode to Improve Distribution in a Recessed Area

Since in most plating we are concerned with the minimum thickness, we can also express the above data in average thickness for the area.

Section of Panel	Average Thickness	Area × Average Thickness
Central 40%	1.0	40
Next 40%	1.25	50
Next 10%	1.75	18
Edge 10%	2.50	25
		133

Hence, on a flat panel you will deposit at least one-third more than is required for a uniform coating thickness. If the back side of the panel is insulated, the edge effect will be increased so that at least 50% more nickel will be used than is necessary for a coat of uniform thickness.

In automatic plating of zinc die-cast and steel automotive components with bright nickel 0.001 to 0.0015 in. thick, the best distribution is obtained economically with 15 to 18-in. anode-to-cathode spacing and an average current density of 35 to 40 amp. per sq.ft. of effective surface area. Effective area means that if the face has an area of 1 sq.ft. and the back of the part gets 30% by weight as much nickel as the face, the part has an effective area of 1.3 sq.ft. Even so, from 1½ to 2 lb. of nickel is used for each pound required for a uniform coat thickness.

Theoretically, the distribution of current due to shape is not affected by the magnitude of the total current. That is, the ratio of maximum to minimum plate thickness due to the shape of a part is a constant. When the ratio changes, some other factor has caused the change. Increasing the current, temperature or agitation will usually give poorer thickness distribution, although the reason for this is not quite clear. However, the influence of edges or high points increases with the thickness of deposit.

It has been noted that with low-concentration copper plating baths, good plate thickness distribution is obtained. On some parts, better thickness distribution is obtained at increased current; the best explanation for this is that the cathode efficiency decreases with increased current density so that more uniform plate thickness results.

The direct cost of nickel plating – the anodes, salts and additional agents – is about $1.00 for each pound of nickel deposited. Each pound of nickel will cover more than 20 sq.ft. with a uniform plate 0.001 in. thick. If some method of improving the distribution factor from 1.33 on flat panels to 1.20 could be found, there would be a direct saving of 13¢ per lb. in addition to the labor, overhead and power savings. The amount of nickel saved by such a development might even be sufficient to give electroplaters all the nickel they have been seeking unsuccessfully.

One possibility is an additive that would decrease the cathode efficiency as current density increased, somewhat like the behavior of anodic coatings on aluminum. Such an additive should not affect the appearance or portective properties of the deposit.

Until such an additive is found, electrical and mechanical means of distributing the current flow offer the best opportunities for conserving nickel. Increasing anode-to-cathode distance will save some nickel; more can be saved by extensive use of insulating shields either hung in the tank when plating certain parts or incorporated into the plating racks.

Die Steel Useful for Ultra High-Strength Structural Requirements

*By JOHN C. HAMAKER, JR.**

The strength, toughness, ductility and thermal stability of a 5% chromium die steel are superior to those of any ultra high-strength structural alloy proposed for aircraft operation in the temperature range of – 100 to + 1000° F. (Q general, J general, AY, TS)

TWO MAJOR PROBLEMS face metals engineers responsible for the selection of alloys for use in aircraft. The most immediate is the need for a steel which can be heat treated to tensile strengths in the range of 220,000 to 280,000 psi. and retain sufficient toughness for structural applications. The few alloys that have been suggested for such requirements have one or more adverse characteristics which limit their general acceptance.

A much greater problem in alloy selection is the so-called thermal barrier or thermal thicket. This is not a fixed speed which an aircraft cannot exceed, as the "sound barrier" was formerly considered, but is determined entirely by the structural materials, especially those used for the skin. As the speed of aircraft increases, the skin temperature increases rapidly as shown in Fig. 1. Speeds in excess of 1900 miles per hr. have been reached and considerably higher speeds are anticipated. The need for new high-strength high-temperature alloys is obvious.

Both problems can apparently be solved by a popular hot work die steel called Hotform which has a unique combination of maximum toughness at ultra high strength levels and elevated-temperature strength that is unsurpassed up to 1000° F. Originally developed 24 years ago by Vanadium-Alloys Steel Co., this steel bears the A.I.S.I.-S.A.E. designation H11 and nominally

*Manager of Research, Vanadium-Alloys Steel Co., Latrobe, Pa.

Table I – Properties of Hotform at Room Temperature

Tempering temperature	Rockwell Hardness	Tensile Strength	Yield Strength	Elongation	Reduction of Area	V-Notch Charpy Impact
950° F.	C-57	311,000 psi	241,000 psi.	3.3%	7.3%	11.2 ft-lb.
1000	54	290,000	235,000	7.8	28.1	15.7
1050	52	268,000	226,000	8.5	31.9	20.4
1100	46	221,000	189,000	11.2	38.5	22.3
1200	33	154,000	124,000	14.1	41.2	29.5
1300	29	136,000	101,000	16.4	42.2	66.8

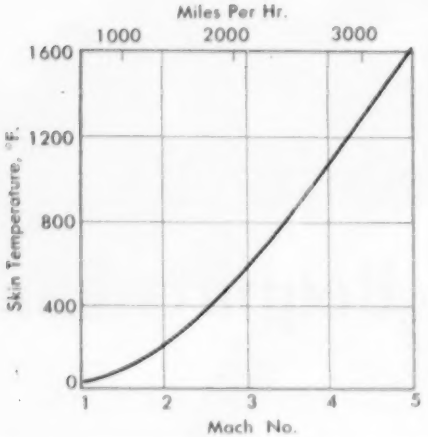


Fig. 1 – Aircraft Skin Temperature for High-Speed Flight in the Stratosphere at Ambient Temperature of –67° F. (From "The Thermal Barrier", by Dr. George Gerard, published here by courtesy of Ordnance *magazine)*

contains 0.40% C, 5.00% Cr, 1.30% Mo and 0.50% V. It has excellent resistance to thermal fatigue in such demanding operations as aluminum die-casting dies, and has proved to be an excellent high-strength material for tool and die engineering.

Room-temperature properties of this material, after air cooling from 1850° F. and double tempering at various temperatures, are summarized in Table I. The maximum true fracture stress, which is indicative of adequate ductility at maximum strength, is achieved by tempering at 1000 to 1050° F. This temper produces 265,000 to 290,000 psi. tensile strength, 225,000 to 235,000 psi. yield strength, 7.8 to 8.5% elongation and 15 to 20 ft-lb. Charpy V-notch impact strength. The impact value at –100° F. is 15 ft-lb. and the fracture is completely tough and fibrous. Notched bend tests maintain full strength and good ductility with bottom radii as small as 0.009 in., indicating minimum notch sensitivity. The elongation and impact strength at various tensile levels appear consistently higher than those for both low-silicon and high-silicon S.A.E. 4340 steel. (See data sheet, p. 96-B.)

The superior ductility and toughness of this relatively high-alloy steel are associated with its unique heat treatment, which produces a stable, stress-free structure while avoiding most of the undesirable features that have beset other high-strength steels. Designed with extremely deep hardenability for the hardening of large die blocks (Fig. 2), this material can be fully hardened in heavy sections by simply air cooling from 1800 to 1900° F. Because it is cooled slowly and uniformly, a structural part arrives at room temperature with much less residual stress than would be obtained from more drastic oil quenching. The very high hardenability also provides assurance against another problem of low-alloy steels–the substandard properties obtained from occasional heats of low hardenability.

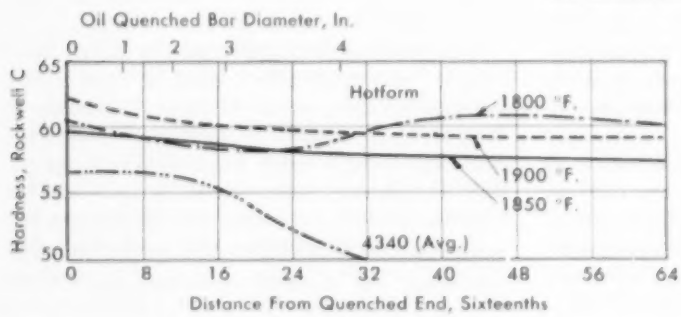


Fig. 2 – Jominy End-Quench Hardenability of "Hotform" Quenched From 1800, 1850 and 1900° F., Compared With Median of 4340 H-Band

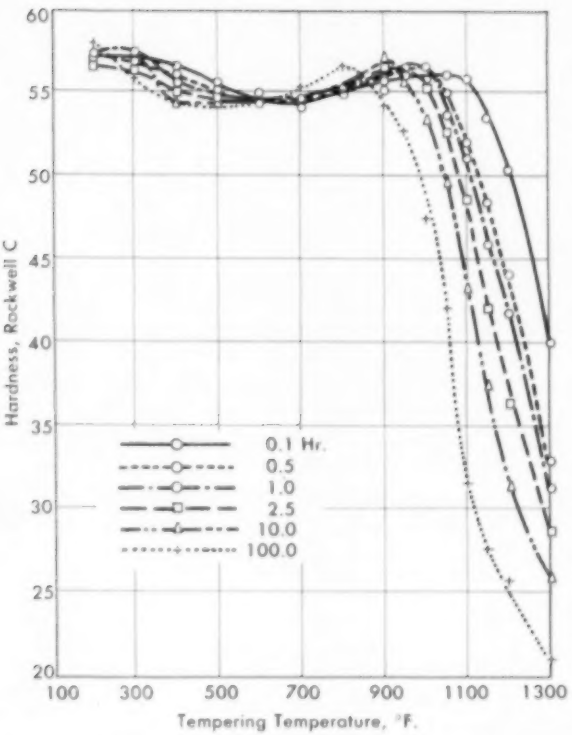


Fig. 3 — Effect of Time and Temperature of Tempering on Hardness of "Hotform" Air Cooled From 1850° F.

The tempering characteristics are particularly outstanding. A secondary hardness peak (similar to that found with high speed steel) appears in the vicinity of 950° F. (Fig. 3), and all tempering is conducted at still higher temperatures to obtain the best combination of strength and toughness. Thus, any residual stresses that may have been set up in quenching are essentially all removed by the very high-temperature "stress-relief temper". Only 50% of the quenching stresses in an oil hardening toolsteel are removed by tempering at 500° F., whereas over 95% are removed by tempering at 1000° F., as indicated in Fig. 4.

Since silicon additions are not needed to raise the tempering range, cleanliness or inclusion problems are eliminated. Similarly, there is no "blue-brittle range" near the desired tempering range. Any tempering temperature beyond the secondary hardness peak can be safely used to obtain the combination of strength and ductility desired. Multiple tempering in this range transforms essentially all of the retained austenite to tempered martensite so that refrigeration treatments are unnecessary.

Mechanical and physical properties after tempering to C-50 are summarized in Table II, and on the data sheet (p. 96-B). At 1000° F., 180,000-psi. tensile strength and 140,000-psi. yield strength are obtained with 30 ft-lb. impact and over 10% elongation. Like all martensitic or ferritic steels, the coefficient of expansion is much lower than that of austenitic stainless steels or other high-temperature alloys. This reduces the stress levels in nonuniformly heated structures and provides more compatible design with titanium, which has a similar low expansion coefficient. The thermal conductivity is also 25% greater than that reported for high-strength stainless steel.

As shown in the data sheet, p. 96-B, its tensile strength ranging from room temperature to 1000° F. exceeds that of all the well-known high-strength heat resisting materials. Its strength-to-weight ratio is superior to those of the strongest titanium alloys, precipitation hardening stainless steel and other high-temperature alloys. The high-strength titanium alloys and 17-7 PH derive their strength from age hardening, and due to structural instability at higher operating temperatures, neither alloy is recommended for operation above

Fig. 4 — Effect of Tempering Temperature on Residual Stress in a Quenched Manganese Oil Hardening Toolsteel

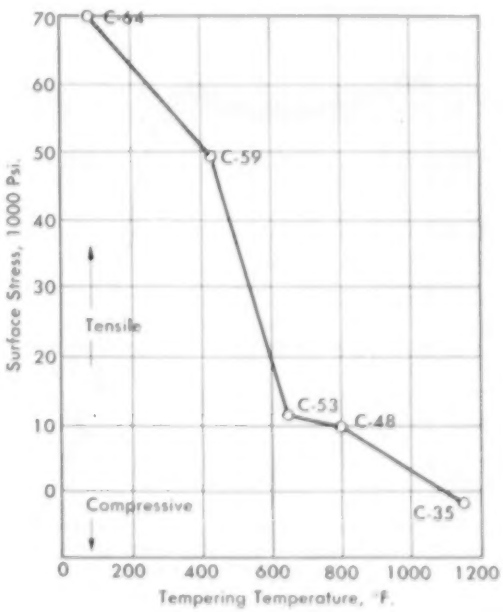


Table II – Elevated-Temperature Properties of Hotform Initially Tempered at 1060° F.

Test Temperature	Rockwell Hot Hardness	Tensile Strength	Yield Strength	Elongation	Reduction of Area	Modulus of Elasticity	V-Notch Charpy Impact
70° F.	C-50	262,000 psi.	215,000 psi.	10.0%	35.8%	30.4×10^6 psi.	21.0 ft-lb.
300	50	245,000	197,000	10.1	36.1	27.7	27.1
500	50	232,000	195,000	9.8	34.5	26.2	30.4
650	49	229,000	191,000	10.0	35.2	27.7	32.0
800	45	219,000	187,000	11.4	38.7	27.3	31.8
900	40	207,000	166,000	12.2	38.9	27.0	29.3
1000	40	180,000	140,000	11.0	35.4	22.6	30.5
1100	32	142,000	105,000	12.8	46.2	21.0	33.2
1200	11	85,000	63,000	18.9	66.6	16.5	59.1

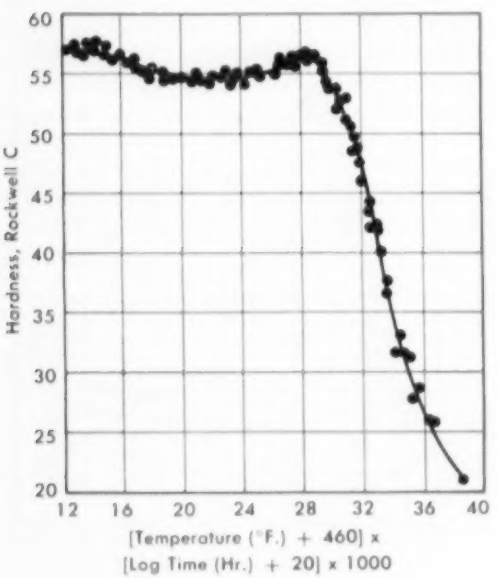
800° F. "Hotform" can be used at temperatures up to at least 1000° F.

Materials of the latter type that derive their strength from the tempering and secondary hardening of martensite tend to be structurally stable and predictable. Their softening with exposure time at elevated temperatures closely follows the empirical tempering relationship devised by Holloman and Jaffe and adapted to alloy steels by Roberts, Grobe and Moersch:

$$\text{Parameter} = [°\text{F.} + 460] \times [20 + \log \text{hr.}]$$

Using the data in Fig. 3, a single curve is derived in which hardness is plotted against values of the parameter (Fig. 5). From this curve, we can quite accurately predict what tempering temperature should be used to provide

Fig. 5 – Parametric Relationship Which Shows Combined Effect of Time and Temperature of Tempering on Hardness



structural stability and essentially constant short-time tensile properties under various operating conditions. For example, the following initial tempering temperature should provide 100-hr. structural stability at the given operating temperatures:

Minimum Tempering Temperature	100-Hr. Operating Temperature
985° F.	900° F.
1040	950
1090	1000
1200	1100

The same parameter technique, developed by Larson and Miller to relate creep-rupture life with short-time tensile properties, can also be applied to this steel for calculating creep-rupture characteristics.

With regard to surface stability, the chromium content provides considerably more oxidation and corrosion resistance than is found in lower alloy steels. In fact, a lower-carbon 5% Cr, 0.5% Mo counterpart of this steel has the designation Type 501 stainless, and is used extensively under the corrosive high-temperature conditions of oil refining. Hot-dip aluminizing may be used to increase resistance to oxidation and corrosion in service and to protect the surface during heat treatment. The component is dipped in molten aluminum prior to austenitizing at 1850° F. The aluminum will diffuse at 1850° F. and increase the toughness of the aluminized layer. Where maximum wear resistance is required, this alloy can be nitrided as readily as the aluminum nitriding steels to obtain surface hardnesses up to Vickers 1300 while retaining the heat treated strength of the core.

This material is produced in all common forms, including billets, forgings, sheet, bars and drill rod. Welding and processing procedures have been established by long experience, and uses are foreseen in many fields.

Coke quenching car, Youngstown Sheet and Tube Co., Youngstown, Ohio. Ductile iron plates, doors, diaphragms, and door hinge brackets have greatly extended the service life and reduced maintenance costs on cars of this type. The castings were held in place with rivets of "Yoloy", a nickel-copper steel produced by Youngstown.

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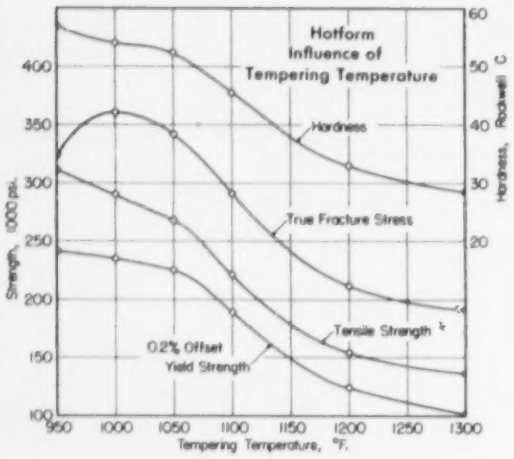
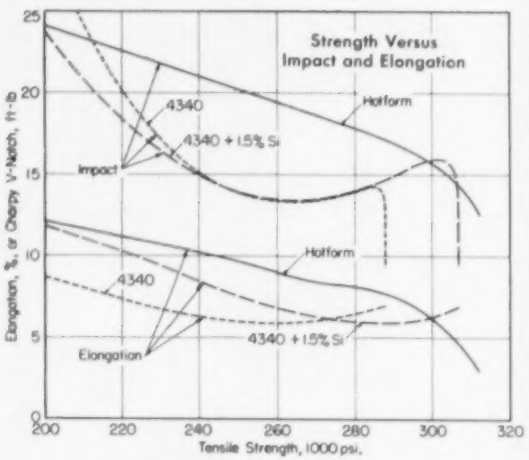
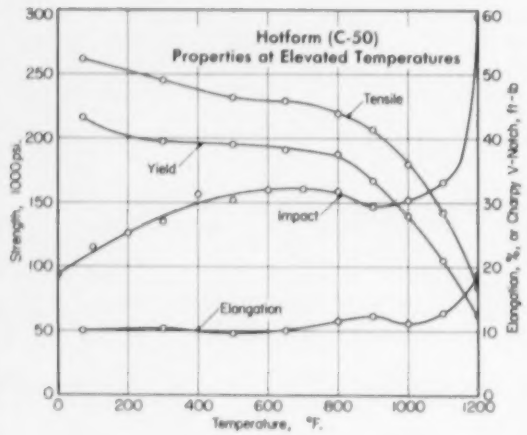
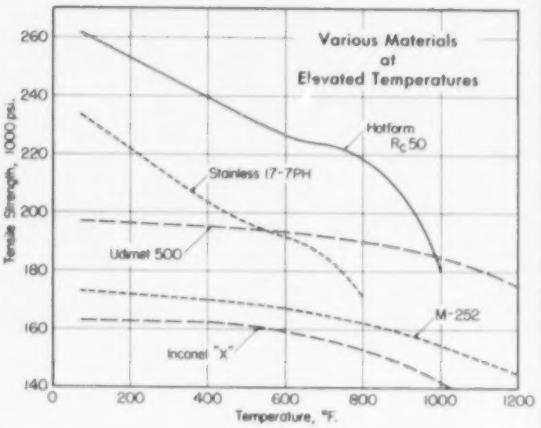
Structural Engineering Properties of Hotform, a 5% Chromium Die Steel

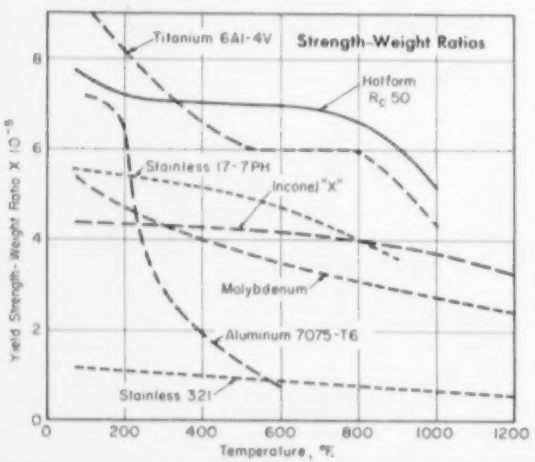
by J. C. Hamaker and V. C. Strang











Physical Properties of Hotform

Composition: 0.40% C, 5.0% Cr, 1.30% Mo, 0.50% V

Density: 7.75 g. per cc. (0.280 lb. per cu. in.)

Mean coefficient of thermal expansion, in. per in. per °F. x 10^{-6}		Thermal conductivity, Btu. per sq. ft. per hr. per °F. per in.	
80 to 200° F.	6.1		
80 to 400	6.5	420° F.	199
80 to 800	7.1	660	197
80 to 1200	7.4	890	196
500 to 1200	7.8	1120	199
800 to 1200	8.1		

Notes on Heat Treatment

Forging: Start at 2000° F., stop at 1600° F.; slow cool in insulating medium.

Annealing: 1500 to 1550° F.; cool at 50° per hr. to 1000° F.; Brinell 183 to 202.

Welding: Preheat to 1000° F.; weld with shielded arc; maintain temperature above 600° F.; slow cool in furnace or insulating medium; full anneal.

Hardening: Preheat at 1450° F.; hold 20 to 30 min. at 1800 to 1900° F. in protective compound, salt or atmosphere; air cool to room temperature.

Tempering: Double temper at 950 to 1200° F.; time and temperature depend on size and hardness desired.

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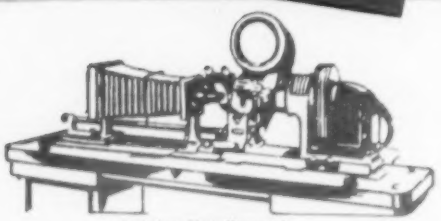

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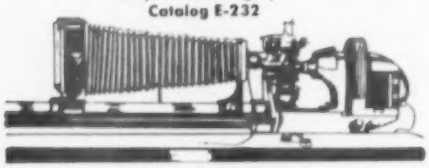

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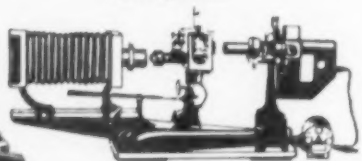

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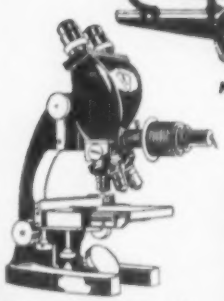

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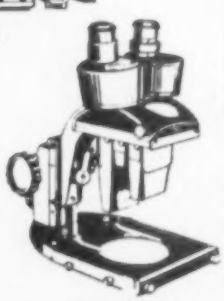

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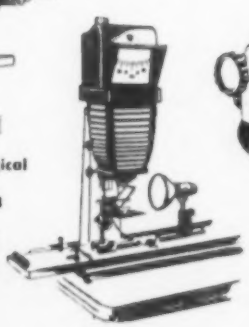

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Recent Studies on Ductile Molybdenum

*By JULIUS J. HARWOOD**

There is nothing inherently esoteric in the fact that commercial molybdenum, naturally ductile, can be embrittled during fabrication. Small amounts of oxygen, as well as nitrogen and carbon, tend to form grain-boundary films which start and propagate cracks between very ductile crystals. A little titanium is most efficient in rendering these impurities innocuous. (Q23, Mo)

IN RECENT YEARS much attention has been given in the United States to molybdenum and its alloys, particularly to evaluate their properties at 1600° F. and higher where they exhibit unexampled creep strength. This advantage has been accompanied by certain drawbacks, notably susceptibility to catastrophic oxidation (which will not be discussed in this article), grain boundary contamination leading to poor ductility at room temperature, the misnamed "recrystallization embrittlement", and deficient toughness of welded joints. These features have obvious importance in the use of the metal in structures or machines.

Norman L. Deuble has presented a useful summary of the properties of arc cast molybdenum in the fourth article of his series in *Metal Progress*, July 1955 issue. Enough parallel studies have been made on metal parts originating as cast ingots and as pressed powder to indicate that, once the mechanical and thermal processing treatments have wiped out the characteristic features of the starting material, quite similar tensile and fatigue properties are obtained at room temperature when tests are made on the two varieties. Ductility in either case depends on refinement of grain structure and redistribution of impurities. What appears to be significantly different grain growth behavior is due to differences in carbon and oxygen content (see Table I), and restriction of grain growth in sintered molybdenum by oxide films.

Purification of Metal – It was to be expected that much attention has been given to the production of molybdenum of an ever higher degree of purity – if only in an effort to explain some of the anomalies in the behavior of supposedly "pure" metal. As seen in Table I, arc cast metal is now notably lower in oxygen and carbon than that produced six years ago. However, to establish the quantitative relationships it was necessary to refine the best metal available, and then add known amounts of impurities.

Two methods were found acceptable, (*a*) vacuum fusion purification, which is really multiple arc melting, and (*b*) solid-state purification, which consists of heating thin sections of commercial molybdenum in high vacuum (10^{-6} mm.) above 1900° C. but below the melting point.

Repeated remelting under high vacuum readily removes oxygen, nitrogen and hydrogen but leaves the carbon about as it was. Consequently, powder metallurgy bar stock, which has a lower carbon content than arc cast molybdenum, was used as the starting electrode material. The last column in Table I describes the resulting double remelted high-purity ingots.

Solid-state purification is equally effective in removing volatile impurities in molybdenum wire and rod up to 0.25 in. Heating in a vacuum of 0.1 micron of mercury for 6 hr. can reduce the oxygen to 0.0003% and the nitrogen to 0.0002% in a sample previously decarburized by heating in flowing oxygen at 1650° C. (3000° F.).

*Head, Metallurgy Branch, Office of Naval Research, Department of the Navy, Washington, D.C. This paper is based on a much longer presentation before the conference on powder metallurgy held in Reutte, Austria, in the spring of 1955 under the title "Some Aspects of the Technology of Molybdenum and Its Alloys". The opinions stated in this article are those of the author and are not necessarily those of the Office of Naval Research.

Table I—Impurities in Refined Molybdenum

	Arc Cast Ingot		Sintered Bar Stock	High-Purity Ingot
	Produced in 1949	Produced in 1955		
Oxygen	0.0018%	0.0002%	0.0007%	0.0002%
Carbon	0.032	0.024	0.003	0.002
Nitrogen	0.005	0.0002	0.0001	0.0002
Hydrogen	0.0001	0.0001	0.00031	0.00005

Embrittlement by Impurities

To prepare metal whose tests are summarized in Fig. 1, the impurities were added to multiple arc melted metal, starting with pressed powder electrodes. Oxygen and nitrogen were introduced into the furnace at low pressure during final melting. Carbon was added as a master alloy in the original electrode.

An unnotched bend test was loaded at a rate of 1 in. per min. which strains the outer fibers somewhat faster than in the ordinary tensile test. The convention was adopted that below the "transition temperature" the bend angle would be less than 4°; above the "transition temperature" the bend angle would be more than 4°. Figure 1 shows that, by this test, minute amounts of oxygen (0.0002%) severely embrittle cast molybdenum. Nitrogen is not as harmful; room-temperature brittleness occurs at 0.003% N. Carbon was the least harmful of the three; room-temperature ductility was obtained with approximately 0.014% C.

Points are shown in Fig. 1 where an excess phase appeared in the microstructure, and the curves seem to break at those points—that is to say, the greatest increase in transition temperature occurs while the trace impurities are present in solid solution or at least so highly dispersed as to be invisible to the microscopist. Once a second phase occurs—usually at a grain boundary—the addition of more impurity has a relatively smaller effect in raising the transition temperature (increasing brittleness).

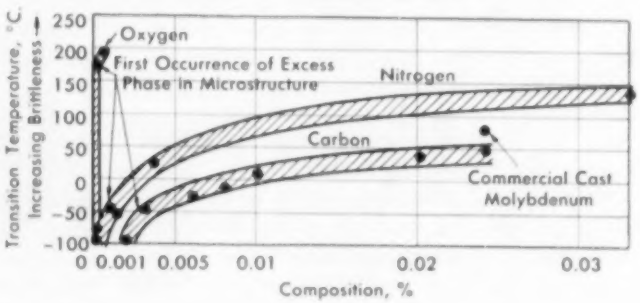
This suspicion, namely, that grain-boundary precipitate was the ruling factor, is confirmed by other evidence. First is metallography (Fig. 2); the grain boundaries of the high-purity control ingot are free from second phases, but precipitated (oxide) phases occur at the boundaries when oxygen—the most potent element—increased from 0.0001% to 0.0006%.

Second is the fact that advances in the techniques of arc melting have resulted in higher purity ingots and an associated decrease in transition temperature. Several years ago the average oxygen content of commercial cast molybdenum was 0.002%, whereas the 1956 product may be as low as 0.0003%. The bend transition temperatures of these carbon-deoxidized ingots are respectively 180 and 80° C. (350 and 175° F.). In comparison, the bend transition temperature of a high-purity, multiple melted molybdenum ingot with 0.0001% O_2 could be as low as −80° C. (−110° F.)

Similarly, the solid-state purification of molybdenum powder also improves its ductility. Even though fully recrystallized—which ordinarily should make the pieces more brittle than the original fibered molybdenum—the purified rods are ductile. Heating for 12 hr. at 2100° C. (3800° F.), while evacuated to about 0.05 micron Hg, reduces the oxygen from 0.0018% to 0.0003% and results in a transition temperature of about −90° C. (−130° F.).

A third fact lending experimental evidence to the belief that oxygen is the most potent agent in embrittling molybdenum is shown in Fig. 3, wherein solid-state purified wires were heated 15 min. at 1485° C. (2700° F.) in very small partial pressures of oxygen and tested at that temperature. It seems clear that the hot metal absorbed oxygen in proportion to the amount in the rarified atmosphere, and as the oxygen content increased the tensile ductility decreased.

Fig. 1 — Effect of Oxygen, Nitrogen and Carbon on Bend Test Transition Temperature of Cast High-Purity Molybdenum. (Battelle Memorial Institute)



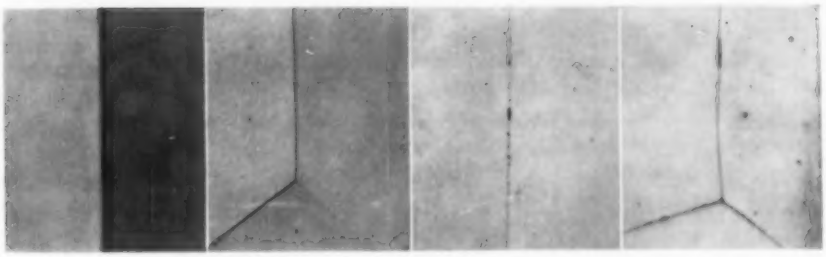


Fig. 2 – Accumulation of Grain Boundary Constituent in High-Purity Cast Molybdenum as Oxygen Increases. Left is the high-purity control ingot, etched in warm ammonium phosphate and hydrogen peroxide, × 2000. Others were etched in Murakami's reagent, × 500; left to right, 0.0001% O_2, 0.0002% O_2 and 0.0006% O_2

Finally an experiment on a wire, 0.04 in. diameter, consisting of a single crystal, is enlightening (Fig. 3). If it is heated alongside a polycrystalline wire in a low pressure of oxygen sufficient to embrittle the latter, the single crystal can be bent into a rat tail around a pin twice the diameter of the specimen. Presumably the single crystal has absorbed oxygen, but it was invisible under the microscope (in solid solution), and there was no hardness gradient observable in microhardness tests, surface to center. In solid solution, oxygen is not a potent embrittling factor. In a single crystal there are no grain boundaries for the second phase to collect in. One precaution is necessary—that there be no small surface grain present on the "single crystal"; if so, fracture will start at the grain boundary and propagate rapidly.

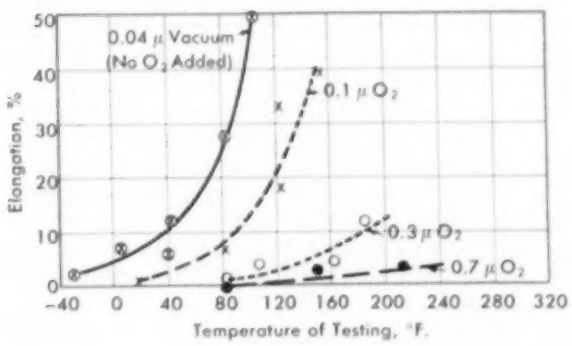
In summary, there is sufficient reason to speculate that molybdenum completely free from oxygen would be ductile at —190° C. (—310° F.). Furthermore, oxygen (and nitrogen and carbon) may embrittle molybdenum in two ways. If sufficiently high, they will precipitate at grain boundaries, and so result in intergranular brittleness. Impurity elements in solid solution (and the room-temperature solid solubility for some of them may be below the limits of analytical sensitivity) will increase the tendency for transgranular brittleness. The two effects may cooperate thus: Discontinuous films at grain boundaries may initiate intergranular cracks which may then propagate transgranularly.

"Recrystallization Embrittlement"—The above investigations throw much light on an exasperating feature in the heat treatment of molybdenum—namely that if a cold worked piece is heated for recrystallization, it would likely lose a lot of its original ductility. Recent findings now establish quite definitely that this is due to contamination from the furnace atmosphere and is not inherent to the recrystallized state. Thus the term "recrystallization embrittlement" is a misnomer and should be dropped.

The ductile behavior of high-purity molybdenum in the as-cast condition supports this. Adequately deoxidized, it can retain ductility after heating 1 hr. in "oxygen-free" atmospheres as high as 2180° C. (3900° F.). Charpy impact transition temperatures of recrystallized molybdenum alloys were often lower than for the as-wrought alloys. Coarse grain size or the process of recrystallization, *per se*, is therefore not the cause of embrittlement. Finally, deoxidation with aluminum, rare earth elements and titanium alleviates high-temperature embrittlement, and the high ductility of molybdenum purified by heating in a high vacuum makes it impossible to ascribe any embrittlement effects to the process of recrystallization.

From a commercial viewpoint the neutralization of harmful impurities, similar to deoxidation practice for steel, would be more feasible than their elimination since

Fig. 3 – Effect of Oxygen Pressure in Atmosphere Upon Ductility of High-Purity Molybdenum Wires, 0.04 in. Diameter Tested in Tension. (Battelle Memorial Institute)



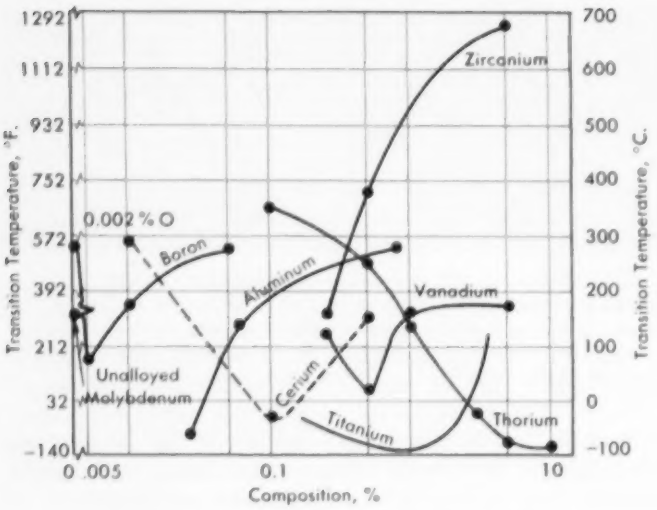


Fig. 4 – Effect of Various Elements on Bend-Test Transition Temperature of Cast Molybdenum. Al, Ti and Th are by analysis of ingot; others are amounts added to melt. Strain rate, 0.038 in. per in. per sec. (Battelle Memorial Institute)

it would be almost impossible to prevent the subsequent contamination of high-purity molybdenum during fabrication.

Therefore a number of elements were studied which have compounds of such stability that they offered some promise of "tying up" the deleterious O_2, N_2 or C. These elements are Al, Ti, Zr, Cr, B, Si, V, Be and Th, and their effects were evaluated by tests on cast ingots. Titanium proved most effective in improving the room-temperature ductility of cast molybdenum and in lowering the transition temperature (Fig. 4). The optimum composition may be that at which the impurities are converted into innocuous inclusions in proper dispersion.

An extensive study of the binary alloys by the Climax Molybdenum Co., summarized very briefly by Deuble in *Metal Progress* for July 1955, revealed also that molybdenum with 0.5% Ti had the lowest tensile transition temperature of any alloy tested, −70° C. (−90° F.) for recrystallized material. This is a real achievement! In notched-bar Charpy tests none of the alloys had markedly superior transition temperature to unalloyed molybdenum.

Cure of Brittle Weldments

The factors responsible for the low ductility of molybdenum weldments are identical to those responsible for the embrittlement of as-cast or recrystallized molybdenum, and the practical problem of improving the ductility of weldments lies in the application of the principles discussed above – namely, high-purity materials or the dispersion of grain-boundary oxides by alloying elements or by hot working.

John Wulff and his associates at Massachusetts Institute of Technology have studied the effects of heat treatment and hot work on welds in arc cast molybdenum and powder metal products. All the characteristics he has discovered are associated primarily with the oxygen content (either initially present or picked up from the welding atmosphere) and indicate that the most likely methods to produce ductile weldments lie, as indicated above, in the use of super high-purity molybdenum and inert atmospheres; hot working the welded zone to disperse oxide networks; or the use of deoxidized molybdenum and filler rods. Sound ductile welds can be made in such metal when the welding is done in high vacuum.

The oxygen content of commercial powder metallurgy molybdenum is usually sufficient to embrittle weldments even when arc welded in purified inert atmospheres. Welds in commercial molybdenum of low oxygen content, carbon-deoxidized and arc cast, are brittle because of carbide precipitation. Commercial inert gases are usually too impure for adequate protection. In addition, the faying surfaces must be clean and free of oxide films.

Such specialized practices are hardly commercial, and consequently alloying elements as deoxidizers or "fixers" are under investigation. To be effective such elements should have a high affinity for oxygen; the metal oxide should have a high melting point, be capable of spheroidization, and have a low dissociation pressure or sufficient stability to lower the pressure of molybdenum trioxide vapor which tends to form when the dioxide is in contact with the metal. Of the numerous alloying elements investigated, titanium in the optimum content for weld ductility is in the same range of composition as results in the lowest transition temperature of molybdenum-titanium alloys.

In fusion welding, oxygen pickup in the weld bead (and consequent embrittlement) is directly related to the oxygen content of the welding atmosphere. Since nitrogen seems to influence

the oxygen pickup, its addition to an "inert" welding atmosphere containing 0.2 to 0.4% oxygen may be helpful. Apparently a reaction between the two gases occurs under the welding arc which reduces the amount absorbed in the bead. However, such oxygen-nitrogen mixtures cannot be substituted for high-purity inert gases to obtain ductile weldments.*

Summary – The data from studies on room-temperature ductility, high-temperature embrittlement, deoxidation and alloying indicate that molybdenum, unless it is of high purity, contains precipitates of oxides, carbides or nitrides at the grain boundaries. When sufficient to produce networks, they result in poor ductility. Heating in vacuum puts these precipitates into solution, and after quenching the ductility is good.

The ductile or brittle behavior of heat treated molybdenum and its alloys is dependent upon the atmosphere in which it is heated as well as the rate of heating, rate of cooling and subsequent reheating conditions. In this an aging process involving grain-boundary precipitates appears to be the primary process.

Deoxidation practice and alloying elements improve ductility by converting the precipitates (oxides, nitrides, carbides) into innocuous forms, by affecting the solubility relationships of the interstitial impurities, and by altering the kinetics of the aging processes.

*Author's Footnote – Since the writing of this paper, techniques have been found for making arc welds in "inert" atmospheres which give welds with moderate ductility.

Infiltration of Cermets for Improved Toughness

*By CLAUS G. GOETZEL and JOHN B. ADAMEC**

Composite structures produced by impregnating porous titanium carbide compacts with a metallic binder have better impact strength and oxidation resistance than conventional cermets. (H 16, SG-h)

THE LONG SEARCH for high-temperature materials for turbine components to operate beyond the temperature limit of the alloyed metals has led to a group of composite materials called cermets, based on structures incorporating ceramics, intermetallic compounds and the so-called "hard metals". These composite materials usually consist of a hard refractory phase bonded by a more ductile metallic phase. The combinations studied have included such a variety of systems as molybdenum disilicide and nickel, aluminum oxide and chromium, zirconium boride and nickel, and titanium carbide bonded with nickel, cobalt or iron-base alloys. The material which seems most promising at present is based on titanium carbide as the refractory phase and various nickel alloys as binder metal.

Although such cermets have been produced over a wide range of binder-to-carbide ratios,

*Vice-President and Director of Research, and Chief Metallurgical Engineer, respectively, Sintercast Corp. of America, Yonkers, N. Y.

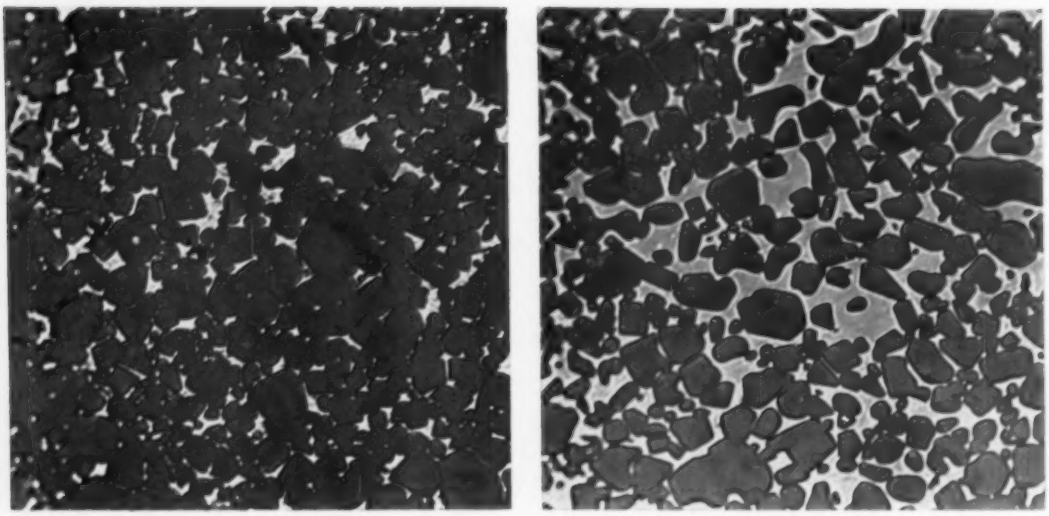


Fig. 1 — Microstructures of Titanium Carbide Cermets. The continuous carbide network shown at the left causes much lower resistance to impact than the discontinuous structure shown at the right. Unetched. 1000 ×

the best combination of physical properties is obtained when the composition contains approximately 60% by volume of titanium carbide. Successful fabrication techniques include sintering the components above the melting temperature of the binder, hot pressing at these temperatures or infiltration of a porous carbide skeleton with the molten binder.

Materials produced by all three methods have met with varying degrees of success but the lack of toughness has so far hindered their acceptance as structural materials for gas turbine components in jet engines. Both impact and fatigue resistance are marginal. Failures which have occurred during the engine testing of titanium carbide-base buckets have generally been located in the upper 25% of the airfoil section or in the neck of the special dovetail-type root. It is believed that high vibratory stresses amplified by poor damping characteristics are partly responsible for airfoil failures and that foreign particle impact at thin sections is responsible for the remainder. There also exists the possibility that inadequate resistance to thermal shock in combination with poor impact resistance may contribute to premature failure of the critical airfoil sections. Fractures in the root sections are believed to be caused by the inability of cermet components to deform plastically so that stress concentrations due to small misalignments can be alleviated.

In view of the persistent shortcomings of the present cermet products, renewed thought is now being given to the employment of so-called "graded" cermet products. The term "graded" means that the metal content in the cermet component varies along one or more directions so that the physical properties of any given section can accommodate the imposed mechanical and thermal conditions. Such a gradation could provide ductility and toughness in areas which require these properties. The same areas would not be subjected to a combination of high temperature and high stress so that either high-alloy cermets or pure alloys could be used. The problem, therefore, is primarily one of selecting appropriate materials and developing a fabrication technique so that cermets of varying alloy content up to pure alloys can be combined into one component. In present jet engine operation, specific temperature and stress conditions in various areas of a turbine bucket are as follows: For the roots, the stress is 20,000 to 25,000 psi. and the temperature is 1200 to 1400° F.; for the top of the airfoil, the stress is about 8000 psi. and the temperature 1600 to 1700° F.; for the bulk of the airfoil, the maximum stress is 12,000 psi. and the temperature may reach 1800° F. at certain critical areas.

It has now been established that the infiltration technique can produce certain types of graded titanium carbide products which possess the desired properties in each of the aforementioned critical areas. Thus it should be possible to overcome the shortcomings in ductility and impact

resistance now encountered in the homogeneous cermet engine components.

The standard infiltration process used for the production of precision products consists of lightly compacting a briquet of ultrafine (less than 5 μ) titanium carbide powder and sintering at a relatively low temperature to form a strong but very porous compact. This skeleton is an exact replica of the finished product in shape, dimensional tolerance and surface smoothness. An investment mold of highly refractory material is formed around the skeleton and subsequently a molten heat resistant alloy is introduced and contacts the skeleton, usually on top, filling all of its interstices by capillary action. Thus, a continuous intertwined two-phase structure is produced upon solidification.

This technique has been modified so that infiltration of the skeleton takes place along preferential paths resulting in metal-enriched areas at the sensitive edges of the airfoil and at the root. By careful control of the heating cycle, shrinkage of the skeleton can be directed to create gaps between the interior surfaces of the investment mold and the exterior surfaces of the skeleton. These gaps become filled with the molten heat resistant alloy during the infiltration process.

Properties of Homogeneous TiC Cermets

The properties of titanium carbide cermets are influenced to varying degrees by the microstructure of the composite material. Impact resistance is sensitive to the uniformity of the spacing and the degree of separation of the carbide grains. Since impact fractures tend to initiate in and propagate through the brittle carbide phase, a structure of isolated well-rounded carbide grains will have a higher impact strength than a structure with angular coalesced grains. The micrograph on the left of Fig. 1 shows a representative structure indicative of low impact strength, where an almost continuous path may be traced through the carbide phase; an impact strength more than double can be achieved by a structure containing more dispersed and isolated carbide grains such as that shown at the right.

Unfortunately, the stress-to-rupture properties tend to decrease with decreased carbide concentration within certain limits, as shown in Fig. 2. The shape of the titanium carbide grains does not seem to affect the stress-rupture properties but there is evidence that the strength decreases with excessive separation. There are also indications that with the higher carbide concentrations required for high-temperature stress-rupture strength there is a marked tendency for coalescence of the grains which appears incompatible with the degree of carbide grain isolation necessary for high impact strength. Thus the achievement of adequate toughness, that is, impact resistance coupled with strength and ductility at various temperature levels up to and above 1800° F., becomes virtually impossible in a homogeneous cermet of the type under consideration.

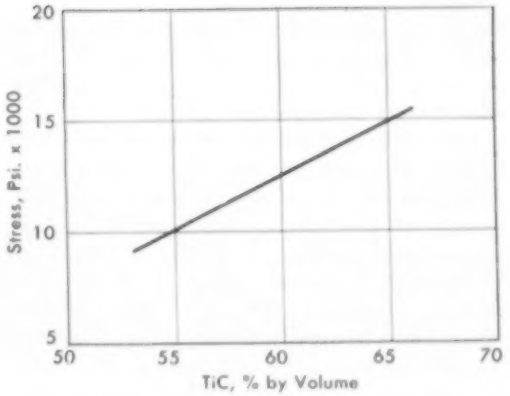


Fig. 2 – Effect of Titanium Carbide Content on Stress to Produce Rupture of Cermet in 100 Hr. at 1800° F.

Graded Components by Infiltration

The problem of combining high impact strength with high stress-to-rupture strength may, however, not be as formidable for an actual turbine component if the high impact and high strength properties, respectively, are placed into those areas where they are most required—that is, in a suitable graded structure. For example, the airfoil section of a bucket with a thick dimension in the central area which tapers out to thin leading and trailing edge sections could consist of such a graded carbide structure. The heavy load-bearing central sections near the root require primarily high stress-rupture strength to withstand the centrifugal force cause by the rotating wheel but need not have the optimum in impact strength since there is enough mass to resist impact fracture; a high carbide concentration may therefore be advantageous. On the other hand, the thin leading and trailing edges should possess the highest possible ductility because there is only an extremely small amount of mass available to bolster these sections against dynamic stresses and impacts caused by foreign particles. Since the edge sections are not re-

quired to carry as heavy a load as the central portion, their structure may incorporate well-separated carbide grains with a corresponding reduction of stress-rupture strength.

The pores of titanium carbide skeletons can be filled with concentrations ranging from below 50 to above 80% by volume so that an infiltrated product with a graded carbide concentration can be produced readily. A graded skeleton can, for example, be formed within certain practical limits by pressing a billet with a higher density at the center, by varying the die fill, or by varying the molding pressure in selected portions. After presintering, the billet is machined into a turbine bucket shape whose leading and trailing edges will have a substantially lower carbide density, and this concentration gradient will be maintained after infiltration.

The graded carbide structure can also be achieved to a certain degree on a shaped product, even when the skeleton is of uniform density. With a selected carbide particle size and proper control of the infiltration mechanism, the edges and other high-energy areas of a blade skeleton tend to be infiltrated preferentially with a greater amount of molten metal contacting the surface than the central areas of the skeleton. Due to this predominance of the liquid metal in the outer areas, a dispersion and separation of the carbide grains is preponderant at the edges. This mechanism is also operative, though much less effectively, at the faces of the airfoil shape.

Nozzle vanes produced with a highly dispersed carbide structure at the edges withstood a ballistics impact test at the trailing edge without exhibiting the brittle-type failure characteristic of conventional cermet materials. The result of a ballistic impact is shown in Fig. 3. The failure at the trailing edge indicates that considerable plastic deformation occurred, and there is no sign of crack propagation through the less ductile central sections of the airfoil.

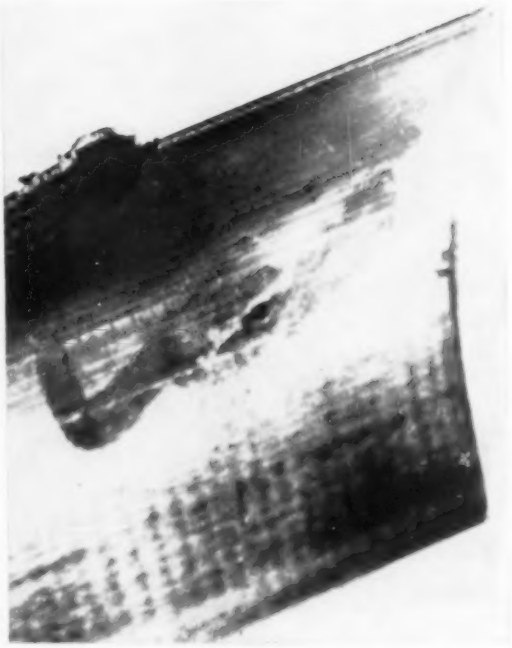


Fig. 3 – Ductile Failure of Infiltrated Cermet Nozzle Vane in Ballistics Test

A second important effect achieved by the

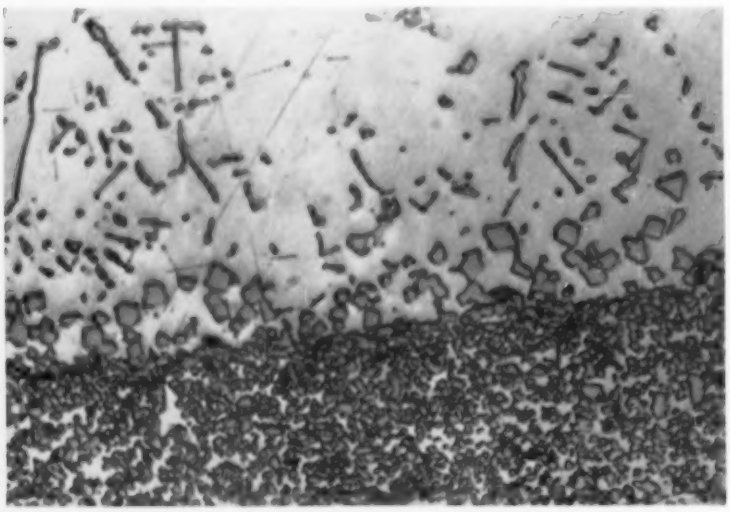


Fig. 4 – Bond Between Metal-Enriched Surface Film and Body of Cermet Component. Unetched. 200×

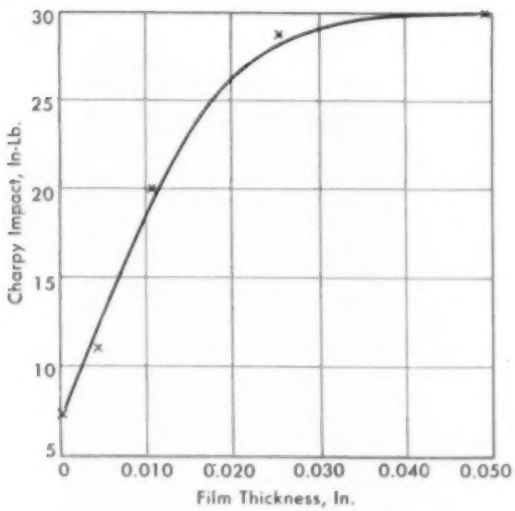


Fig. 5 – Effect of Surface Film Thickness on Impact Strength of Titanium Carbide Cermet

infiltration process is the integral attachment of a metallic surface film to the carbide body. This metal-enriched surface film is merely an extension of the alloy phase of the infiltrated structure and it is saturated with titanium carbide. Since it is produced as an integral part of the carbide body, there is no evidence of a parting line or separation at the transition zone. The structure and bonding of the metal-enriched surface film to the base structure are shown in Fig. 4.

A variation in thickness of the surface film has a marked effect on impact resistance. This was established in a series of impact tests of samples 3/16 × 3/16 in. which had been cut and ground from infiltrated rectangular bodies so that one face would have a metal-enriched layer. The specimens so produced were tested with the metal-enriched face of the bar placed in the tension fiber on a pendulum Charpy impact machine using a 50-in-lb. pendulum hammer and a span of 1.050 in. The results are shown in Fig. 5. A surface film of 0.006 to 0.010 in. more than doubled the impact resistance, and a film about 0.025 in. thick increased the impact resistance fourfold to a value of about 30 in-lb. This improvement may be attributed to the plastic deformation achieved at the metal-enriched surface which greatly reduces the tendency for crack propagation into the core of the test bar.

It is apparent that this method of improving impact resistance may be used to great advantage in high-temperature engine components such as turbine buckets and nozzle vanes. Critical areas subject to ballistic impact, such as the leading and trailing edges of the airfoil, may be made appreciably more ductile by a metal-enriched layer or encasement.

Metal-Enriched Airfoil Encasements

Infiltrated turbine buckets have been produced on a pilot plant production basis with a metal-enriched surface closely controlled to a thickness ranging between approximately 0.010 and 0.030 in. at the leading edges, 0.020 and 0.060 in. at the trailing edges and 0.002 and 0.010 in. on the concave and convex faces of the airfoil. Metallic layers of even greater thickness have been achieved experimentally by careful control of the infiltration variables. For example, a porous layer of refractory carbide and alloy powder was applied to a titanium carbide skeleton in preferred areas prior to insertion in the investment mold. Upon infiltration of the skeleton, the porous surface layer was co-infiltrated and then dissolved by the molten infiltrant, resulting in a metal-enriched surface layer of extensive depth.

Coupled with the noticeably improved impact resistance is an equally significant enhancement of the high-temperature oxidation resistance of the metal-enriched casing as compared to the unprotected carbide body. The depth of penetration of oxide in the metal film after 24 hr. exposure at 1800° F. was found to be reduced to about one-fifth. What appears of even greater significance is the observation that the impact resistance remained at the original level, as contrasted to unprotected titanium carbide composites where it was often found nearly decimated by such treatment. Moreover, it may be expected that, thanks to the better ductility of the metal-enriched film, the high-temperature fatigue and thermal shock resistance of the infiltrated titanium carbide products would be greatly enhanced.

By forming a continuous frame-like structure around the edges and an encasing envelope around the convex and concave faces of the airfoil, a serious shortcoming of present titanium carbide-base turbine components might readily be overcome. Engine tests have shown that a catastrophic failure of a turbine wheel often will result from the impact fracture of one cermet bucket. Upon impact, the bucket shatters and the flying fragments in turn hit the other cermet buckets on the wheel and cause them to shatter. With the incorporation of a ductile metal envelope in the design of the bucket, incipient cracking on impact of the critical edge areas

would be greatly minimized. If it did occur, the fragments would be restrained and held together in much the same way a picture frame will prevent a cracked glass from falling out.

The second serious type of premature cermet bucket failure in engine tests occurs in the roots across the fir-tree serrations or the modified dovetails. Such failures indicate that the stresses in this area are greatly aggravated by the method of attaching the brittle component to the turbine disk. Normally, the ductile root of conventional metallic buckets with fir-tree serrations allows for stress equalization and plastic deformation due to stress raisers caused by misalignment. Again, the precision infiltration process appears to be the logical answer to the production of titanium carbide buckets having a root that consists either partially or entirely of the ductile, strong superalloy. By application of the principles outlined for the formation of the metal-enriched airfoil encasement, it is also possible to form a large metal section at the root by an extension of the infiltrant phase of the structure. An experimental J-47 turbine bucket with metal-enriched encasement around airfoil and machined serrations in the metal-enriched root is shown in Fig. 6 alongside.

Fig. 6 – Infiltrated Titanium Carbide Bucket With Metal-Enriched Encasement Around Airfoil and Machined Serrations in Metal-Enriched Root

Outlook for Infiltrated Components

Graded titanium carbide-base turbine buckets and nozzle vanes should perform satisfactorily in jet engines under normal conditions of operation involving the relatively moderate stresses and temperatures mentioned earlier. However, there still exists the question of technical and economic attractiveness of a product of this type which must be proven to the satisfaction of the jet engine builder before mass production of the component can be contemplated.

Improvements in the high-temperature strength of certain superalloys, especially by vacuum melting, make it almost mandatory that cermet-type components perform up to a temperature noticeably above that of the latest superalloys developed – that is, certainly above 1800° F. and preferably up to as high as 2000° F. in the hottest areas of nozzle vanes and bucket airfoils. Naturally, they would have to perform equally satisfactorily at any intermediate temperature that would be encountered during heating and cooling.

It is the authors' conviction that the graded component of the type and structure producible by the infiltration technique will answer this requirement, possibly constituting the only practical solution to the problem. If care is taken that the metal-enriched encasement around airfoil and root is not impaired by the diffusion of embrittling elements, it should be possible to increase, by suitable addition to the titanium carbide, the intrinsic strength and oxidation resistance at elevated temperatures. Not only additions of other carbides, but also borides and silicides, may serve this purpose. As a result, a complex titanium carbide-bearing base structure may be developed which, when infiltrated and encased with the best present superalloys, will yield jet engine turbine components useful in the super high-temperature range.

Fe-Al-Mo Alloys for High-Temperature Use

*By J. F. NACHMAN and W. J. BUEHLER**

The light weight, excellent oxidation resistance and high strength at elevated temperatures of iron-aluminum-molybdenum alloys indicate their potential utility as replacements for iron-chromium and iron-chromium-nickel alloys. (SG-h)

IN IRON-BASE ALLOYS, aluminum improves the resistance to oxidation more effectively than equivalent amounts of chromium. It also increases high-temperature strength and decreases the density of such alloys. The combination of good high-temperature properties and light weight indicates that the iron-aluminum alloys should be useful in such demanding applications as blades in the final stages of axial-flow compressors and as skins for missiles and ultra high-speed aircraft.

The Thermenol alloys which contain 10 to 18% aluminum and 2 to 4% molybdenum have been studied extensively by the Naval Ordnance Laboratory to determine their potentialities and limitations. The investigation indicated that Thermenol may replace Type 403 stainless steel as compressor blading and can possibly be substituted for higher alloy steels used in high-temperature service such as industrial furnace hardware. The alloys have relatively low ductility at room temperature but the ductility increases rapidly at temperatures above 800° F.

*Both authors were with the Magnetics Division, U.S. Naval Ordnance Laboratory, Silver Spring, Md., when this article was prepared. Mr. Nachman is now research metallurgist, Denver Research Institute, Denver, Colo.

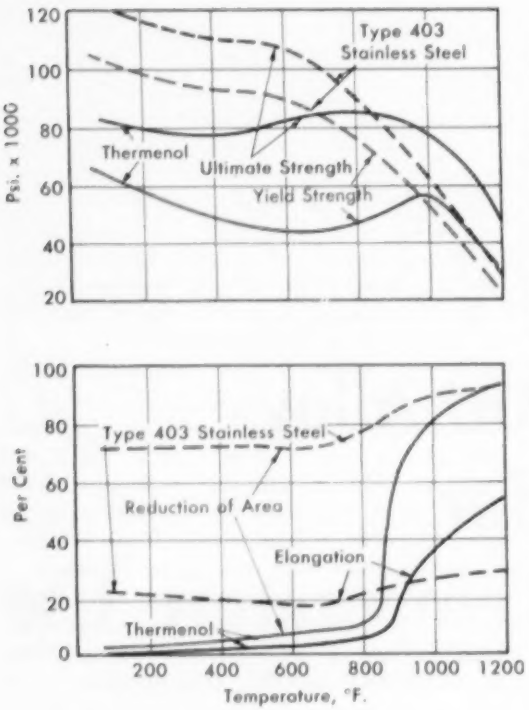


Fig. 1 – Mechanical Properties of Thermenol and Type 403 Stainless Steel. (Courtesy Thompson Products, Inc.)

The mechanical properties of Type 403 and a Thermenol containing 16.5% aluminum, 3.5% molybdenum and 0.06% carbon are shown in Fig. 1. It is apparent that below 800° F., Type 403 is superior but that Thermenol has better properties at higher temperatures. The increase in both ductility and strength of Thermenol may be attributed to an order-disorder transformation.

The low density of Thermenol (0.24 lb. per cu. in.) makes its strength-weight ratio superior to many common aircraft structural materials at intermediate temperatures, as shown in Fig. 2. Above 450° F., its strength-to-weight ratio is better than that of 17-7 PH, a precipitation hardening stainless steel currently considered one of the more promising aircraft materials.

The excellent high-temperature oxidation resistance of the iron-aluminum alloys has been recognized for some time. The Thermenol alloys have an oxidation resistance superior to all other known high-temperature alloy systems. The addition of 3% molybdenum to an alloy containing about 16% aluminum was not found to be detrimental in any way to the oxidation resistance. At 2200°F. the oxidation rate is only 0.0003 in. per year. Some castings have been heated in air to temperatures as high as 2500° F. for several hours without any perceptible damage due to oxidation. This superior resistance to oxidation can be attributed to the stability of the tightly adherent oxide coating which is formed upon the surface of the alloys when exposed to oxidizing conditions.

Comparative tests were conducted at the Naval Engineering Experiment Station to study the effects of vanadium-induced accelerated oxidation upon Thermenol and 25-20 Cr-Ni stainless steel at 1600° F. The results of these tests are shown in Fig. 3. It can be concluded that Thermenol is roughly twice as resistant to V_2O_5 attack as the 25-20 stainless steel.

A few qualitative experiments were carried out at the Naval Ordnance Laboratory to determine the effect of powdered zinc upon Thermenol at bright red temperatures. No deleterious effect could be detected on either the oxidized or cleaned surface. Stainless steel treated in a similar manner is severely attacked.

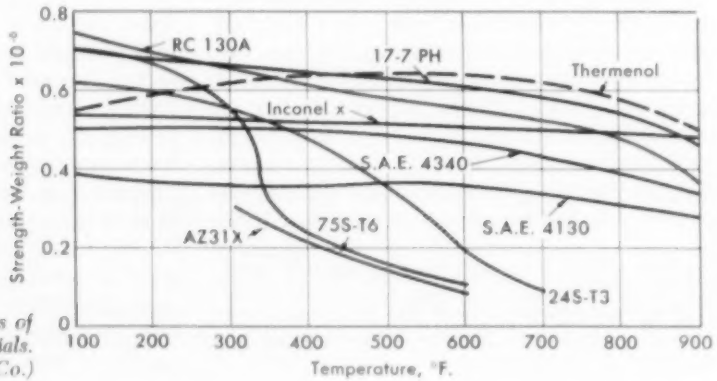


Fig. 2 – Strength-Weight Ratios of Aircraft Structural Materials. (Courtesy Glenn L. Martin Co.)

The resistance of Thermenol to the corrosive attack of highly oxidizing solutions is excellent. Its resistance to fuming nitric acid used as rocket fuel has been reported to compare favorably with the noble metals and higher cost alloys. Sodium hydroxide solutions in all concentrations were found to have a negligible effect upon Thermenol. Solutions of organic acids and concentrated ammonium hydroxide were also without effect. On the other hand, solutions of ferric chloride and hydrochloric acid are quite corrosive. A severe pitting type of corrosion was found to occur with ferric chloride solutions.

Qualitative tests showed that Thermenol is fully resistant to foods and food products as, for example, grapefruit, lemon, onions, tomatoes, meats and the common vegetables. This resistance to corrosion and its abililty to maintain a sharp edge immediately suggest the use of Thermenol for cutlery and other kitchen ware.

No corrosive effect was noted on Thermenol exposed to a boiling 40% solution of magnesium chloride for 96 hr. In this respect its corrosion resistance is equal to that of Types 302 and 430 stainless steels.

There is considerable disagreement between individual laboratories regarding the resistance of Thermenol to salt spray. The results of recent tests have shown that Thermenol is more resistant to salt spray than heat treated Type 403. The corrosive attack on Thermenol is general whereas the stainless steel is pitted severely.

Formability of Thermenol is dependent upon ductility and is affected to a great extent by the temperature. Sharp 90° bends can be obtained readily on 0.020-in. thick sheet in a cold rolled and a recrystallized condition if the forming is conducted at temperatures of about 570 and 480° F., respectively. Shearing and punching operations can be carried out at room temperature if the sheet is not too thick. Sheet up to 0.040 in. in thickness has been successfully sheared at room temperature. Temperatures of about 300° F. have been used for shearing and punching operations on thicker sheet. More complex forming operations require higher temperatures. For instance, parts have been success-

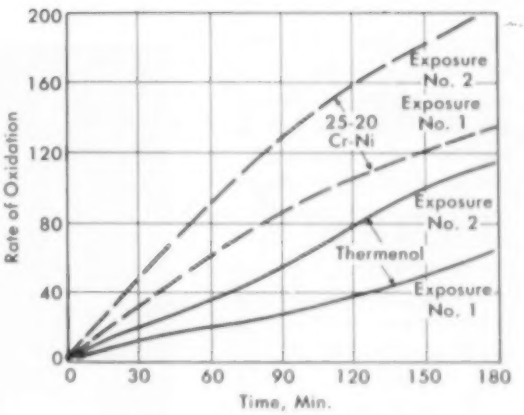
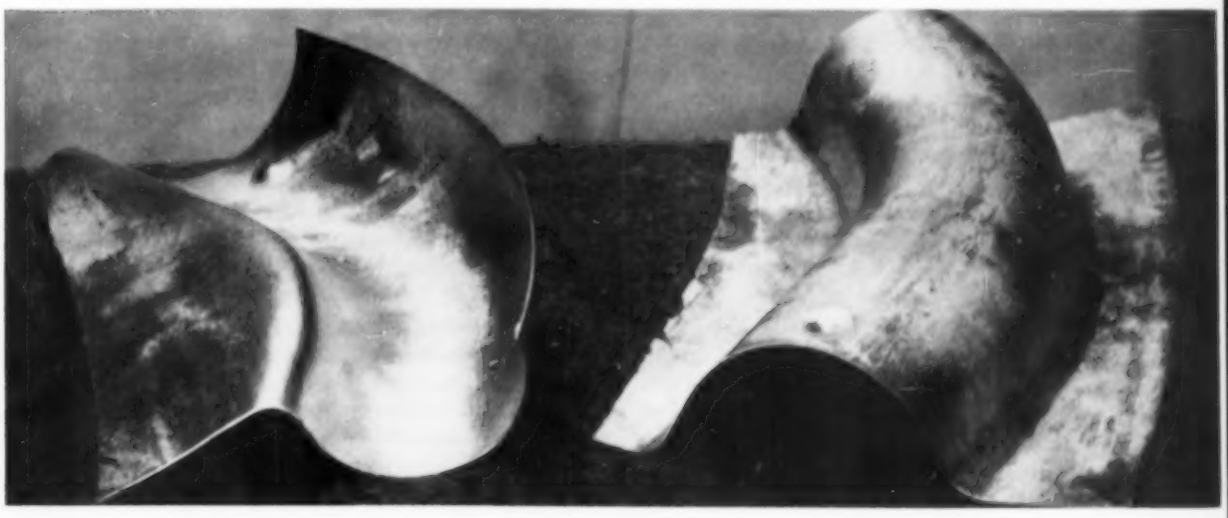


Fig. 3—Oxidation Rates in Vanadium-Bearing Atmospheres at 1600° F. for Thermenol and 25-20 Stainless Steel

Fig. 4—Thermenol Duct Halves Drop Hammer Forged at 1200° F. (Courtesy Glenn L. Martin Co.)



fully hand formed at 1000° F. and dimpled at 900° F. Some formed parts are shown in Fig. 4 and 5. Note that these temperatures correspond to the range of temperatures at which maximum ductility occurs. Recent work at the Naval Ordnance Laboratory indicates that considerable improvement in room-temperature ductility of sheet may be possible.

All ordinary machining operations of turning, threading, drilling, milling, shaping and tapping can be satisfactorily performed on Thermenol if sharp tools and slow speeds are employed. Since the alloy work hardens very rapidly, excessive speeds should be avoided. High speed steel and carbide tools have been found to perform equally well. Satisfactory results have been obtained with surface speeds of 20 to 40 ft. per min. and a depth of cut of ¼ in. or less. The surface finish is, in general, dependent upon the grain size, the finer-grained material producing the best results.

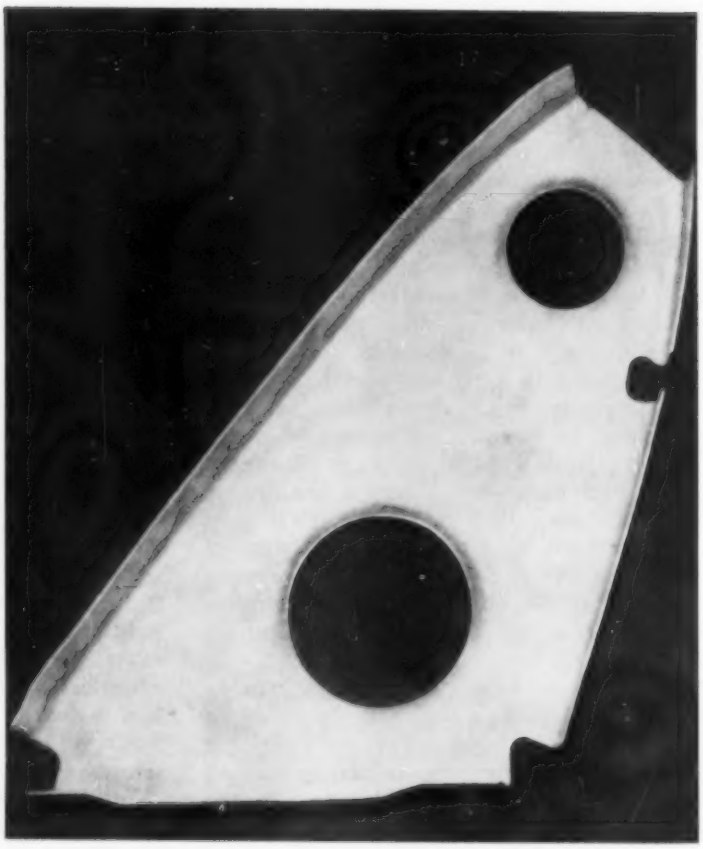


Fig. 5 — Thermenol Section Hand-Formed at 1000° F. (Courtesy Glenn L. Martin Co.)

Because of the low heat conductivity of these alloys, grinding tends to produce local overheating and leads to the formation of fine hairline cracks. These propagate upon subsequent hot working. To eliminate this condition, suitable grinding wheels and coolants must be used. Thermenol has been ground successfully using small feeds on the order of 0.0005 in. More rapid grinding is possible with a mixture of sulphochlorinated fats and mineral oil as coolant.

Summary

1. The physical and mechanical properties of Thermenol show its possible suitability for use in jet engine compressor blades. In this capacity it compares favorably with Type 403 stainless steel. In addition, Thermenol displays superior stress-rupture strength, damping capacity at high stress levels, resistance to salt spray corrosion and it is 15% lighter in weight.

2. On the basis of strength-to-weight ratio, Thermenol sheet in a cold rolled condition shows better strength properties at temperatures above 450° F. than many of the common aircraft structural materials, including 17-7 PH stainless.

3. Unlike most other alloys, the strength of Thermenol does not decrease rapidly with an increase in temperature. The strength up to about 1000° F. remains almost constant and, in fact, shows a slight increase in a certain range of temperatures. This phenomenon is apparently related to an order-disorder transformation.

4. Corrosion resistance of Thermenol to common chemical solutions is good. It is fully resistant to oxidizing solutions, to organic acids and to food products. Resistance to oxidizing and sulphur-bearing atmospheres at elevated temperatures is excellent.

5. Parts may be formed from sheet stock by warming the material prior to forming.

Properties of Titanium Melted Under High Vacuum

*By R. L. FOLKMAN and M. SCHUSSLER**

The ductility and notch toughness of titanium melted under vacuum pressures in the low-micron range are appreciably better than those of titanium melted under the usual vacuum pressure in the low-millimeter range. (C 25, Ti)

VACUUM MELTING in either induction or arc furnaces improves the physical and mechanical properties of many ferrous and nonferrous alloys by removing volatile impurities and minimizing contamination by hydrogen, nitrogen and oxygen. Titanium alloys must be melted under vacuum or inert atmosphere because they are so reactive, and they are now the major product of vacuum arc-melting furnaces.

Recently, a trend toward lower furnace pressures for titanium melting has become apparent and furnace pressures in the *low-millimeter* range are now being used successfully. Pressures in the *low-micron* range are generally not used in commercial production but our studies have indicated that such high-vacuum melting can improve appreciably the properties of wrought titanium. Single-melted ingots of titanium, semicommercial in size, show significantly less contamination during melting and lose much more hydrogen gas when melted under pressures in the low-micron range than ingots which had been melted under reduced pressures of 300 to 400 mm. The ductility and notch toughness of mill products prepared from the high-vacuum melted ingots are significantly improved.

The titanium sponge employed for these studies was prepared by the sodium reduction process in the prototype production unit of the Electro Metallurgical Co., and represented sponge samples selected to cover a broad range of composition and hardness. Laboratory melting was conducted in a consumable-electrode arc furnace employing 2 × 2-in. cold pressed and welded consumable electrodes. Direct current up to 1500 amp. and 60-cycle alternating current up to 3000 amp. are supplied to the furnace from d-c. selenium rectifiers and a-c. welding transformers, respectively. Melting rates from 60 to 200 lb. per hr. were attained, depending on the power input. Water cooled copper crucibles, 4 or 6 in. ID, were employed, permitting ingot weights up to 100 lb., although 10 to 30-lb. ingots were usually made for laboratory studies. The vacuum system consists of a KS-600 two-stage oil ejector diffusion pump backed by a KD-220 mechanical pump.

Semicommercial ingots, 9 in. in diameter and weighing between 300 and 400 lb., were melted in the high-vacuum consumable-electrode arc-melting furnace which was developed and operated by the Climax Molybdenum Co. of Michigan. The installation has an automatic continuously forming, consumable-electrode mechanism, and alternating current is employed for melting.

Plate was prepared by forging the ingots, after scalping to a 2-in. thick slab, beginning at 1650° F. and finishing at 1300° F. The slab was spot ground, then hot rolled to ⅝-in. plate, be-

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Table I – Effect of Furnace Pressure on Composition of Titanium Sponge

	Carbon	Oxygen	Nitrogen	Hydrogen
Average sponge composition	0.040	0.09	0.006	0.0150
Ingot melted under 5 to 60μ pressure	0.037	0.125	0.006	0.0032
Change in high-vacuum melting	−0.003	0.035	—	−0.0118
Average sponge composition	0.047	0.096	0.0085	0.0141
Ingot melted under 300 to 400 mm. pressure	0.045	0.148	0.0105	0.0117
Change in reduced pressure melting	−0.002	0.052	0.002	−0.0024

ginning at 1400° F. and finishing at 1100° F. The plate was annealed for 1 hr. at 1300° F. and air cooled.

After grit-cleaning and descaling by grinding or pickling, sheet was prepared by hot rolling the plate to 0.063 in. beginning at 1400° F. and finishing at 1100° F. The hot rolled sheet was grit-cleaned, annealed for 20 min. at 1300° F., air cooled, grit-cleaned and pickled in 17% aqueous hydrofluoric acid to remove 0.003 in.

The 300 to 400-lb. ingots from the semi-commercial heats were worked in commercial mill shops to plate and sheet, using procedures similar to those described above.

Although the comparative chemical analyses of ingots melted under pressures in the millimeter range and the low-micron range fail to disclose any marked differences in the levels of carbon, oxygen and nitrogen, trends are certainly indicated. The changes in analyses from sponge to ingot are summarized in Table I.

The data indicate slight carbon reductions with both furnace pressures. Lower levels of oxygen and nitrogen contamination were obtained with the high-vacuum melts, and of course a much greater degree of hydrogen reduction resulted from melting in the low-micron range. The relation between ingot hydrogen contents and furnace pressures employed in this work is shown in Fig. 1. It is of interest to note that the ingot hydrogen values of less than 50 ppm. are relatively independent of the charge hydrogen contents which range from 70 to 220 ppm.

From theoretical considerations, the vapor pressure of a gaseous constituent such as hydrogen in the melt is a function of bath temperature and the quantity of gas in the melt. If the total pressure above the bath is greater than the vapor pressure of the gas in solution, removal of the gas occurs by a diffusion mechanism until an equilibrium is established between the partial pressure of the gas above the melt and the amount of that gas in the melt. Such a process may result in a gaseous boundary layer between the melt surface and atmosphere which tends to slow down the rate of removal of the gas. On the other hand, if the total pressure above the bath is less than the vapor pressure of the gas in the melt, removal of the gas occurs by a boiling mechanism which produces much higher rates of gas removal.

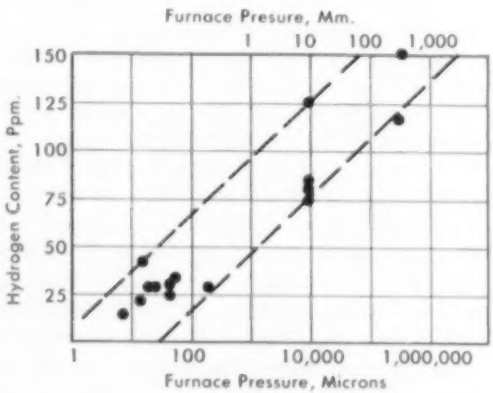
Further confirmation of the higher ingot purity achieved by melting in the micron range rather than in the millimeter range is shown in Fig. 2. This plot relates the hardness values determined on ingots to the "button" hardness values used to characterize the sponge. Button hardness values were measured on 50 to 100-g. buttons prepared according to accepted industrial procedures for tungsten arc-melting of representative sponge compacts under inert atmosphere. All hardness values representing reduced pressure melts may be seen to fall above the hardness values representing high-vacuum runs (less than 60 μ.) The difference ranged from Brinell 5 to 25 for material of equal button hardness.

The results may be interpreted in two ways:

1. High-vacuum melting results in less contamination of the sponge than the button melting procedure which employs higher pressures.

2. High-vacuum melting produces a higher degree of purity in the melt by removing trace

Fig. 1 – Effect of Melting Furnace Pressure on Hydrogen Content of Titanium Ingots



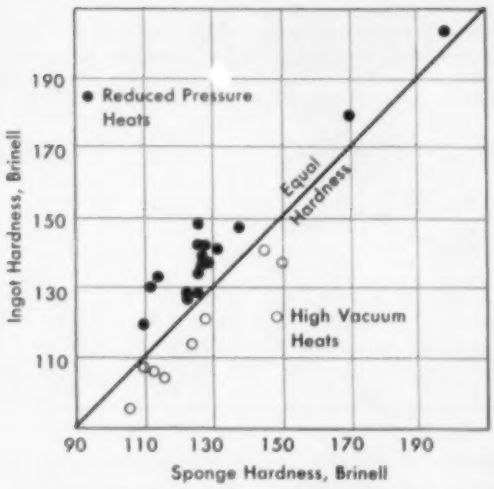


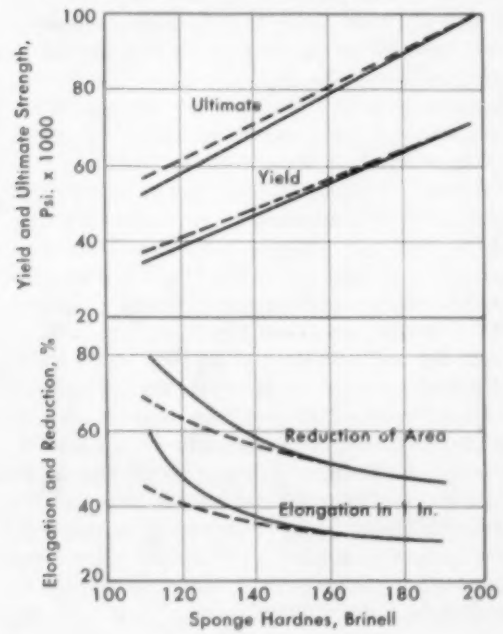
Fig. 2 – Relation Between Hardness of Titanium Sponge and Ingot as Influenced by Furnace Pressure

elements of high vapor pressure, or by promoting deoxidation-type reactions, or both.

Most of the data point to the former interpretation since the hydrogen removal and slight carbon reduction noted with the high-vacuum melts could not account for the hardness decrements noted. Further, spectrographic analysis has failed to reveal any significant changes in trace metallic elements between sponge and ingot. However, in the light of the high vapor pressures of some trace elements and because of the difficulties encountered in sampling and analyzing these elements in trace quantities, the second interpretation of the facts may not be completely ruled out.

Titanium sponge is characterized in commercial practice by relating the mechanical properties of wrought products to the sponge hardness. The mill producer can then predict and control the mechanical properties of mill products produced from a given sponge blend. The relationship of tensile properties of mill products to sponge hardness is used herein to demonstrate improvements in tensile properties associated with high-vacuum melting. The tensile properties of wrought plate obtained from ingots melted under high vacuum (less than 60 μ) and reduced pressure (300 to 400 mm.) are compared in Fig. 3.

Fig. 3 – Effect of Furnace Pressure on Mechanical Properties of Titanium. Solid lines are for high-vacuum heats; the dotted lines represent reduced-pressure heats



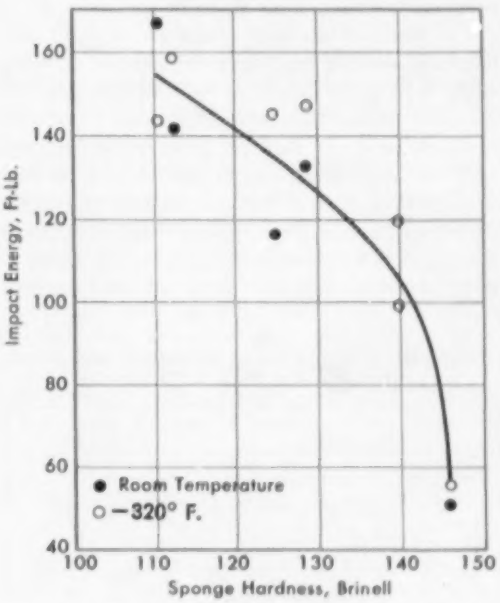


Fig. 4 – Impact Strength of High-Vacuum Melted Titanium at Room Temperature and −320° F.

The curves representing properties of plate prepared from the reduced-pressure melts were derived from data obtained on 10 and 30-lb. heats which were single-melted from consumable electrodes under 300 to 400-mm. furnace pressure. The curves representing the high-vacuum melted material were obtained on the 300 to

Table II – Tensile Properties of Titanium Sheet Made From High-Vacuum Melts

Sample	Brinell Hardness of Sponge	Yield Strength	Tensile Strength	Elongation
Plate, annealed 1 hr. at 1300° F.	111	36,600 psi.	55,000 psi.	43.0%
	125	42,000	62,500	37.0
Sheet, cold reduced 88% to 0.06 in., as rolled	111	94,700	116,300	12.5
	125	101,600	125,200	15.0
Sheet, cold reduced 88%, annealed at 1300° F.	111	32,000	53,400	42.0
	125	34,600	54,600	38.0
Sheet, cold reduced 94% to 0.03 in., as rolled	111	101,600	124,500	9.0
	125	100,700	126,500	10.0
Sheet, cold reduced 94%, annealed at 1300° F.	111	32,200	53,700	36.0
	125	34,300	54,600	37.0
Sheet, hot rolled to 0.06 in., annealed at 1300° F.	111	35,000	55,500	39.0
	125	39,000	61,800	34.0

400-lb. heats which were single-melted under pressures ranging from 20 to 60 μ.

The linear relationship between strength and hardness and the nonlinear decrease in ductility with increasing hardness is characteristic of material melted by both methods. However, it should be noted that the data representing the high-vacuum melted titanium show gains in tensile ductility of 10 to 15% accompanied by slight decreases in strength at lower hardnesses, and that the data for the reduced-pressure melted material correlate well with data obtained on full-sized commercial ingots melted from sodium-reduced sponge.

Table III – Effect of Aging on Impact Strength of High-Vacuum-Melted Titanium

Treatment	Impact Strength*	
	72° F.	−320° F.
Annealed	108	130
Aged at 210° F. for 1 hr.	112	136
Aged at 210° F. for 16 hr.	114	136
Aged at 210° F. for 100 hr.	127	128
Aged at 210° F. for 1000 hr.	125	113
Aged at 570° F. for 1 hr.	126	124
Aged at 570° F. for 16 hr.	123	133
Aged at 570° F. for 100 hr.	117	130
Aged at 570° F. for 1000 hr.	120	127

*Average of two standard V-notch Charpy tests; ft.-lb.

The low levels of ingot contamination and resulting improvements in ductility contribute to improvements in the formability characteristics of wrought products prepared from the high-vacuum melted ingots. The tensile properties obtained on cold rolled, and cold rolled and annealed samples representing two of the semi-commercial heats high-vacuum melted, from sponge of Brinell 111 and 125 are listed in Table II. For comparative purposes, tensile properties are shown representing the original plate material in the mill-normalized condition, and finally 0.06-in. sheet which had been hot rolled from the plate and annealed. Both 88 and 94% cold reduction passes were made without intermediate anneals and were accomplished with little, if any, edge checking.

Impact data obtained on annealed plate from semicommercial-sized ingots melted under high vacuum from six different lots of sponge of different hardness levels are shown in Fig. 4. At room temperature and at −320° F., impact values in excess of 100 ft-lb. are obtained on high-vacuum melted titanium up to sponge hardness values of about Brinell 140 (equivalent to 50,000 psi. yield strength in the plate.) In addition, the absence of a transition temperature in all of these tests also indicates the excellent notch toughness. Comparative impact strength values for material processed from reduced-pressure heats range up to about 50 ft-lb.

Significant deterioration in notched-impact properties of commercially pure titanium can occur when the material is aged at room temperature for times up to 700 or 800 hr. Samples representing one of the high-vacuum melted 300 to 400-lb. heats were aged at 210 and 570°F. for times up to 1000 hr. to accelerate any aging effects that might occur, then were tested for impact strength. This study was conducted to determine the effect of the relatively low level of interstitial elements resulting from the high-vacuum melting on notch-impact properties after prolonged aging. The results of this test, summarized in Table III, show that no apparent aging effect occurs with times up to 1000 hr. at temperatures up to 570° F.

Heat Treating Instructions for Toolsteel

*By WILLIAM P. LOEHRER**

An instruction sheet accompanying each shipment of toolsteel has eliminated heat treating difficulties for small-volume users. (J general, TS)

TRADITIONALLY, toolsteels have been sold by brand name and only in recent years has a serious attempt been made to classify them with a standard identification system. Consequently, information on heat treatment is usually available on the basis of brand name only and is supplied by the respective producers in the form of a handbook, booklet or bulletin.

This method of providing information about the characteristics of different kinds of toolsteel, and the correct practice to follow in heat treating them, was and still is quite acceptable under certain circumstances. Unfortunately, many small users, because of their limited or infrequent purchase of toolsteel, do not have the necessary reference books to consult and consequently have nothing to turn to for guidance in heat treating the steel. Many of these users have been disappointed in a toolsteel occasionally, not so much because the steel was faulty but because the system for conveying information about it was poor.

It was just such a situation as this that prompted Ryerson to develop an individual data sheet for each of its different kinds of toolsteel, to be sent to the customer along with the steel. The plan was to show the hardenability of the steel in the form of a curve giving the average hardness reading. It was believed that this would accomplish the objective of making available with each shipment of toolsteel, all needed information concerning its hardenability.

The Jominy test was and still is used successfully to provide customers with heat treating directions for each lot of alloy steel which they receive. Because of our successful experience with this system, we attempted to find a similar kind of hardenability test which would provide the necessary information for toolsteel in the form of a curve. Unfortunately, because of the effect of mass and other factors which influence hardenability, it proved impractical to prepare an instruction sheet which included such a hardness curve. The use of a curve tended to make the sheet complicated and difficult to comprehend by the type of user the instructions were intended to help.

A simpler and much more satisfactory method was a hardness chart which gives the hardness as quenched and the quenching temperature required for each size of cross section. The hardness attained at a number of different tempering temperatures is also listed. Working temperatures are shown for quenching, annealing, forging and normalizing, and recommended practices are also provided for quenching and annealing. To assure positive relationship between the steel shipped and the instruction sheet pertaining to it, the customer's name, order number and date, and the identification color painted on the steel are included on the sheet.

In metropolitan areas in which Ryerson steel service plants are located, the appropriate instruction sheet is sent with the steel as it is delivered by company truck. In other areas, the sheet is mailed to the person previously designated to receive such information. Usually this person is the man charged either with the responsibility of heat treating the steel on the premises or with sending it to an outside shop for treatment.

In use for approximately six years, the heat treating instruction sheet has resulted in a much improved supplier-customer relationship. It takes the guesswork out of heat treating toolsteel, by providing reliable, on-the-spot information in readily understandable form.

*Manager, Alloy and Stainless Steel Sales, Joseph T. Ryerson & Son, Inc., Chicago.

Correspondence . . .

Multiple Crucible Arc Melting Furnace

LEMONT, ILL.

An arc furnace for the melting of buttons of refractory alloys contains several unique features. Seven different alloys can be melted in one charging cycle. As seen in the diagram, the furnace is approximately 12 in. diameter and 27 in. high. Seven crucibles, 1 in. diameter by 0.5 in. deep, are machined in a circular copper pad, equally spaced around a 3.62-in. diameter. The copper pad is the top of a water chamber, a rubber O-ring providing a watertight seal.

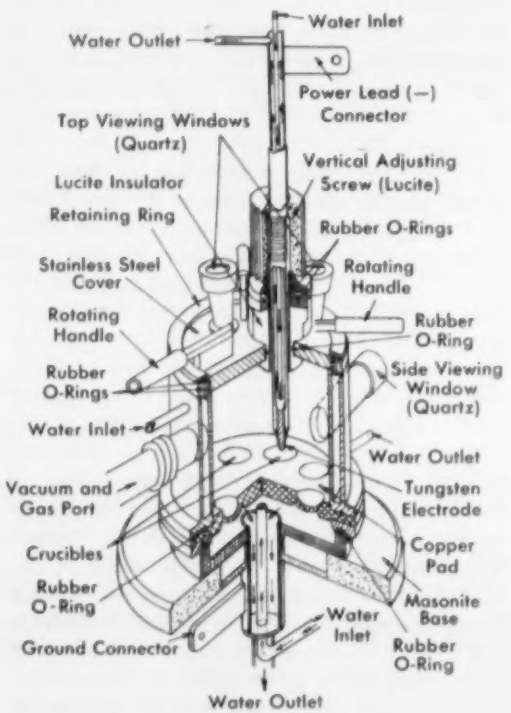
The central body of the furnace is a double-wall stainless steel cylinder, 6.755 in. inside diameter by 7.93 in. high. The bottom end is welded to a stainless steel flange, the top to a stainless steel ring, both of which close the channel formed by the double walls and through which cooling water is circulated. This protects the connections to vacuum and inert gas supply and the quartz viewing window through the side. The bottom flange is screwed to the copper pad containing the molds. Rubber O-rings provide a vacuum tight seal between the component parts.

The furnace cover is a stainless steel plate, 7 in. diameter by 0.625 in. thick. Screwed to it are lucite electrode supports (which also serve as an electric insulator), two viewing windows, and three handles. The position of the electrode support is such that its vertical axis traverses (upon rotation of the cover) the same circle which locates the crucibles. Note the rubber O-rings providing a vacuum seal around the cover plate, a design which allows complete rotation of the cover, moving the electrode from one crucible to another. The cover is held down by a brass retaining ring screwed to the top ring of the central body.

The electrode assembly consists of a copper tube with a central water channel and an annular return. Mid-length is brazed a 3.5-in. brass sleeve with threaded exterior, fitting into an aluminum adjusting screw insulated with lucite. In operation the bottom end of the adjusting screw rests on a spherical surface of a brass nut attached to the lucite support, so the screw can raise or lower the electrode assembly. There is enough clearance and movement in a modified Wilson seal arrangement so the tungsten tip can be revolved in a 1-in. circle, assuring that the arc can play over all parts of the charge.

A Lincoln welding generator operating on a 3-phase 220-volt current is the power source. It is capable of developing slightly in excess of 500 amp. direct current. Most melting is done within the range of 200 to 400 amp. at 15 to 20 v., and is adjusted as needed during melting. A high-frequency spark unit is used to start melting thus:

(*Continued on page* 118)



Multiple Crucible Arc Melting Furnace

For producing the New

CHROMIUM · NICKEL · MANGANESE STAINLESS STEELS

ELECTROMET offers a variety of alloys designed to suit your specific needs

for CHROMIUM

- **SIMPLEX low-carbon ferrochrome**—chromium 63 to 66%, carbon max. 0.010% or 0.025%.
- **Low-carbon ferrochrome**—chromium 67 to 71%, ten carbon grades from 0.02 to 2% max.
- **Medium-carbon ferrochrome**—chromium 66 to 70%, carbon 2.25 to 3%.
- **High-carbon ferrochrome**—chromium 65 to 70%, five carbon grades from 4.5 to 7%.
- **Low-chromium, high-carbon ferrochrome**—chromium 57 to 64%, carbon 3.5 to 5%.
- **"EM" ferrochrome-silicon**—chromium 39 to 41%, silicon 42 to 45%, carbon max. 0.05%.

for NITROGEN ADDITIONS

- **SIMPLEX nitrogen-bearing, low-carbon ferrochrome**—in 2% and 5% nitrogen grades, containing 62 to 65% chromium and 60 to 63% chromium respectively.
- **Nitrogen-bearing, low-carbon ferrochrome**—chromium 65 to 70%, in 0.75%, 1.25%, and 2% nitrogen grades.
- **Nitrogen-bearing, electrolytic manganese metal**—containing approximately 93% manganese (metallic basis) and 6% nitrogen.

for MANGANESE

- **Electrolytic manganese metal**—with minimum manganese content, on a metallic basis, of 99.9%.
- **Low-carbon ferromanganese**—manganese 85% to 90%, six carbon grades from 0.07 to 0.50% max.
- **MANSILOY alloy**—manganese 60 to 63%, silicon 28 to 31%, max. 0.07% carbon.

for additional information

Please contact the nearest ELECTROMET office. Ask for ELECTROMET's new 4-page brochure on electrolytic manganese and the booklets on melting low-carbon stainless steel.

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ELECTRO METALLURGICAL COMPANY
A Division of Union Carbide and Carbon Corporation
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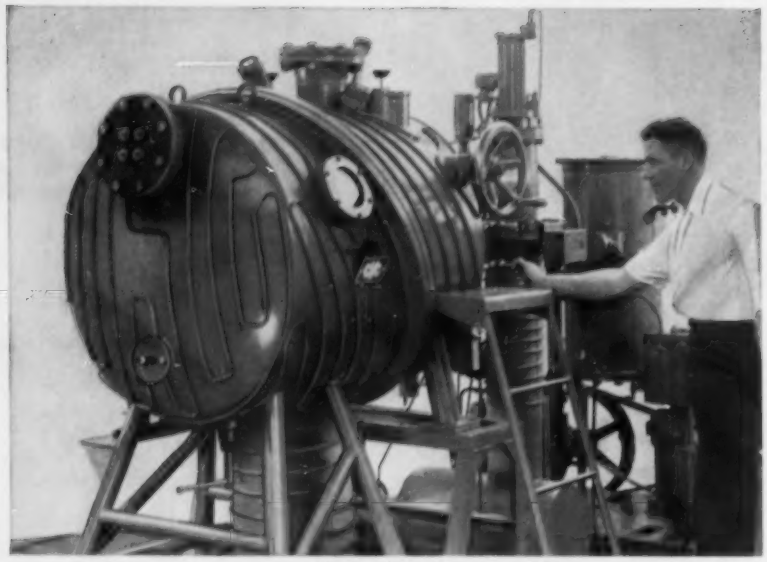
Division of Union Carbide Canada Limited, Welland, Ontario



Process observation, alloy additions, pouring, temperature and pressure readings, high frequency control, valve sequencing—all focus around one center of operation.

Small but versatile

a high-vacuum furnace for lab and pilot plant

CEC's 5 to 50 pound melting and casting furnace offers:

Three-way casting: Melts of 5, 12, 17, 30, or 50 pounds can be cast in single or multiple molds—or centrifugally.

Ease of materials handling: All parts of the furnace interior are within arm's reach. The oblique angle flange connecting the chamber sections provides unusual vertical clearance for removing molds directly with a crane. A deep mold well provides 33" under the crucible lip for pouring bar-type ingots.

Complete controls: A manual bridge-breaker assembly is combined with a water-cooled, nonfogging sight tube for optical pyrometry. A sampling device and a thermocouple assembly are standard accessories. Interlocking of the pneumatic vacuum line valves makes for safe and proper cycling.

The mold well is water-cooled. Electric feedthroughs are provided for mold heating.

Ample pumping: A 2-stage diffusion-ejector pump brings the system swiftly to the low micron Hg pressure range, with plenty of reserve capacity for pressure surges from alloy additions, deoxidation, and pouring.

Write for illustrated bulletin No. 4-30 that lists complete specifications, accessories, and design features of this remarkably versatile furnace.

This view of the mold chamber shows deep well for single molds, indexed table for multiple molds (optional) and drive mechanism for centrifugal casting (optional).

CEC

Consolidated Electrodynamics

Rochester Division, Rochester 3, N. Y.

formerly Consolidated Vacuum

NATIONWIDE COMPANY-OWNED SALES AND SERVICE OFFICES

Arc Furnace . . .

The high-frequency pulse is first superimposed on the welding generator voltage. Once the direct current arc is established the high-frequency current is turned off manually. A Welch Model 1397 B mechanical pump can evacuate the furnace to 2 microns (2×10^{-3}mm. Hg) in less than 5 min.

Melting is done in argon or helium atmospheres or mixtures of both at a pressure of 1 lb. gage. The gases are used as received from the U.S. Bureau of Mines and the Cleveland Wire Works of General Electric Co. On occasion the gases are purified by melting a zirconium getter button in one of the crucibles for about one minute prior to starting on the six remaining ones.

S. T. Zegler and J. Terandy
Associate Metallurgists
Argonne National Laboratory

Machining Hard and Brittle Materials

Melbourne, Australia

Some conflicting statements in the article on "Machining Hard and Brittle Materials", by R. C. Hall in *Metal Progress*, August 1956, p. 78, require some elucidation. In the precis at the head of the article, it is said that electric arc machined surfaces are "free from burrs and strains" but in the text it is stated that work by other investigators shows surface layers to be affected to depths of the order of 0.0015 in. [The precis was written by the Editor, rather than by Mr. Hall.]

Work at Aeronautical Research Laboratories of the Department of Supply, Commonwealth of Australia, reveals that chromium-base alloys, pure copper, aluminum, nickel and austenitic and ferritic steels all have strained surfaces after electric arc machining.

In wrought chromium alloys crack networks developed (see p.120) and were from 0.006 to 0.008 in. deep depending upon the capacitance of the condenser bank and the automatic cutting rate employed. Back reflection X-ray techniques revealed lattice distortion to extend from 0.004 to 0.006 in. into the material.

(Continued on p. 120)

How to save on critical alloys and still get high alloy turbine performance

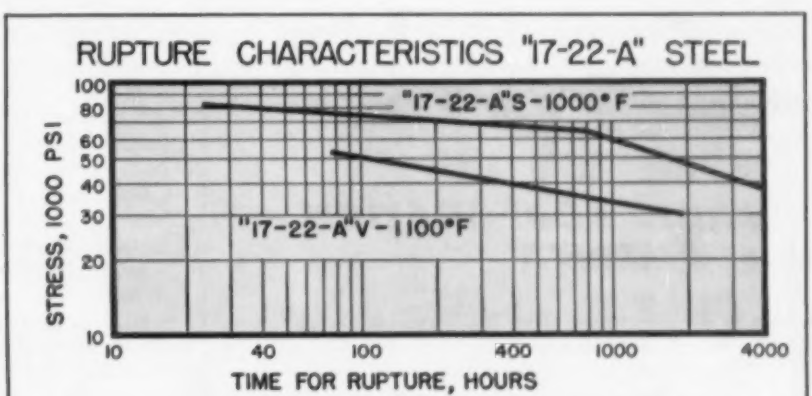
USE "17-22-A" STEELS

Contain less than 3% alloy... give maximum strength to 1000° and 1100°F

YOU don't nave to use an expensive high alloy steel for gas turbine or other parts that operate up to 1000° and 1100° F. You can use "17-22-A" steels made by the Timken Company—*low* alloy steels—to do the same jobs. They give *high* alloy performance, save critical alloys, cut costs. They contain less than 3% alloy, yet they give maximum strength up to 1000° and 1100° F.

You get more advantages. "17-22-A" steels resist heat checking and thermal cracking. They are readily workable up to 2300° F. They are easily machined and welded. And maximum high temperature properties can be developed by normalizing and tempering, minimizing the possibility of distortion and quench cracking.

Send for complete information on "17-22-A" (S) steel, and its companion analysis, "17-22-A" (V), recommended for temperatures up to 1100° F. Ask for Technical Bulletin 36A. And call upon our technical staff for help with your high temperature steel problems. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO".



Stress-rupture curves show strength of "17-22-A" (S) at 1000° F and "17-22-A" (V) at 1100° F.

TIMKEN *Fine Alloy* STEEL

TRADE-MARK REG. U.S. PAT. OFF.

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS STEEL TUBING

Figure 1 shows the microstructure of a steel after it has been quenched at 500° F. The same specimen is shown in Figure 2 after reheating for one hour at 800° F. An original automotive paint surface is shown in Figure 3; Figure 4 is the same surface after the binder has broken down and free pigment particles have appeared, forming a whitish surface layer.

In producing its great line of cars "with the forward look," the Chrysler Corporation uses the RCA Electron Microscope to inspect many of the materials. These studies cover steel, paint finishes, rubber parts, metal powders, brake linings, and the extremely fine colloidal particles used for reinforcing fillers in plastics and rubber.

The investigations, which are headed by Dr. D. M. Teague of the Chrysler Physical-Chemical Research Department, also have been broadened to include foundry smoke and the effect of wear upon metallic parts.

RADIO CORPORATION of AMERICA

More and more the use of the RCA Electron Microscope is becoming mandatory throughout industry for the high magnification and resolution it affords. Find out how the Electron Microscope can help you . . . to determine the structure of materials, control quality, cut costs, save time, accelerate development work. Installation supervision is supplied and contract service by the RCA Service Company is available, if desired. For complete information, write to Dept. M-72, Building 15-1, Radio Corporation of America, Camden, N. J. In Canada: RCA VICTOR Company Ltd., Montreal.

Machining . . .

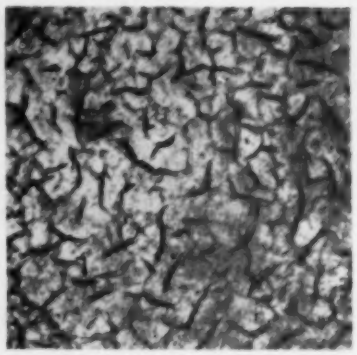


Fig. 1 — Cracks in a Chromium-Base Alloy After 0.004 In. Had Been Removed From the Surface by Electropolishing. 20 ×

Other work seems to indicate that the above troubles may be overcome in metals and alloys susceptible to ductile-brittle behavior but that cutting to produce strain-free surfaces even in ductile metals is apparently impossible.

S. T. Quass
A. O. O'Brien

Forgeability

Paris, France

Of all the processes for shaping metallic materials, the different variations of hot work — such as forging, rolling, extrusion — are by far the most rapid, the most economical and the most likely to produce the best mechanical properties, especially for making long pieces of a uniform cross section such as tubes, bars and shapes. It works so well because of the plasticity of the material. Most hot metals can be deformed to a great extent without rupture or tearing — at least within certain limits of temperature where the metal is sufficiently "forgeable". or susceptible to considerable deformation without cracking. It is, in short, a tendency toward cracking (sometimes called "crackability") which limits the scope of these shaping processes, crackability being in a way the reverse of forgeability.

In most general terms, forgeability depends upon:

1. Factors pertaining to the metal being worked, and especially to its grain size and even more so to the freedom from inclusions or segrega-

Steel-Weld FABRICATION

Use WELDED STEEL for Greater Strength with Less Weight!

Being machined above is one of 164 Tripods produced and machined by Mahon for use in the world's largest continuous grinding and polishing machine to be employed in the production of plate glass. Weldments, in almost any type of heavy machinery give you greater strength with less weight—and the additional advantages of greater rigidity and predictability. If you can use weldments in your products, you can turn to Mahon for complete service including design, or redesign, fabrication, machining and assembling. The parts and assemblies illustrated here are typical of thousands of Steel-Weld Fabricated units produced by Mahon for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment. You, too, will find in the Mahon organization a unique and reliable source for welded steel in any form . . . a source with unusual facilities where design skill and advanced fabricating techniques are supplemented by craftsmanship which assures you a finer appearing product embodying every advantage of Steel-Weld Fabrication. See Sweet's Product Design File for information, or better still, have a Mahon sales engineer call at your convenience.

THE R. C. MAHON COMPANY • Detroit 34, Michigan

Sales-Engineering Offices in Detroit, New York and Chicago

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

Forgeability . . .

tions and consequently its method of manufacture.

2. Other factors depending on operating conditions, particularly the temperature of the metal and the speed and mode of deformation.

3. The condition of the surface of the ingot or billet – which depends on other operating conditions such as the atmosphere in the heating furnace, and tool lubrication.

From these statements it follows that for a given metal or alloy, depending on its purity and method of manufacture, there is a thermal zone or safe margin of temperature wherein hot working under definite operating conditions is possible. Under those conditions the material possesses adequate forgeability. This safe working range must be wide enough for commercial operation.

Now, forgeability and its safe thermal range also depend in large part on the degrees of constraint imposed on the metal during its deformation. Without entering into an analysis of the plastic deformations under one, two or three degrees of constraint, let us say that the possibilities of deformation without cracking vary inversely to the degree of liberty left to the material to deform in various directions. Since the metal is practically incompressible and, on the other hand, breaks only by cracking due to tensile stress or by oblique slip due to shear, deformation is most favored by constraints in compression.

To clarify the ideas of "degree of liberty" and "compression deformations", two extreme examples might be considered:

1. Hydrostatic compression. The metal cannot deform in any direction – except in a direction where there is *less* exterior pressure than on the other regions of the surface.

2. Hydrostatic expansion. In the extreme this would be an explosion in the center of a hollow sphere. Expansion would then occur in all directions.

By hydrostatic compression very fragile substances like marble can be deformed plastically.

On the other hand, no metallic matter holds up without "brittle" cracking under severe hydrostatic expansion.

The two industrial processes which are closest to these two ideal conditions are:

1. Extrusion. The metallic billet compressed in a cylindrical container except at a small orifice at the exit, through which the metal flows.

2. Drifting. This imposes radial expansion in all directions around an axis.

Possibility of deformation and its amplitude are the maximum in the first instance and the minimum in the second, for one metal and in given physical conditions.

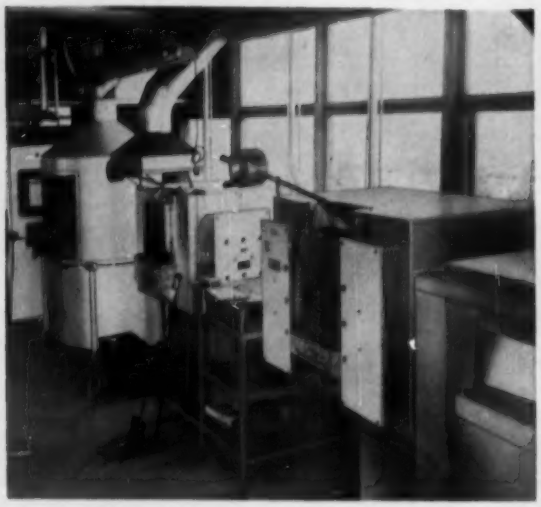
Between these two there are the following, increasing in degree of liberty:

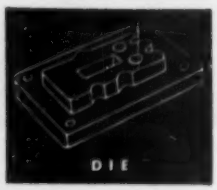
Die swaging
Stamping
Forging or upsetting in closed dies
Rolling in closed grooves
Rolling between smooth cylinders
Forging on the anvil

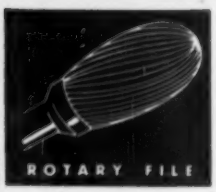
Drawing or extrusion thus seems to be the process which requires the minimum of forgeability. For this reason it is used when other processes, especially rolling, cannot be used or give unsatisfactory results – for example, cause excessive cracking at edges. A particularly striking industrial example is leaded alpha brass, which can readily be extruded hot, yet cannot be rolled hot.

In drawing and especially in extrusion, the lubricant is very important. The use of glass in the extrusion of steel was described in *Metal Progress* for January 1956.

ALBERT PORTEVIN







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...a size for every tool!

For maximum economy and satisfaction of operation, select the SENTRY Diamond Block best suited for the size tool you heat treat.

However, if you do not have a SENTRY Furnace as yet, it can be difficult to imagine the high degree of hardening perfection the SENTRY Diamond Block Atmosphere can achieve for you on your High Speed or High Carbon High Chrome steel tools.

We suggest the use of the proper SENTRY Diamond Block for a specific size tool, because we know SENTRY owners are perfectionists. They want the best – that's why they bought the best: SENTRY Furnaces!

If you want perfection, simplicity of operation, outstanding economy and the ultimate in heat treating quality . . . then YOU want SENTRY – SENTRY Furnaces and SENTRY Equipment!

Learn about the best. Compare it with the rest. Send for

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Write

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THE SENTRY CO. · FOXBORO · MASS.

SPENCER
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The illustration shows Rockwell furnaces for carburizing, crucible melting, bright annealing, casting annealing, aluminum annealing and coil wire annealing—all equipped with Spencer Turbo-Compressors.

are recommended by

THE W. S. ROCKWELL CO.

Since 1918, now more than a quarter of a Century, Rockwell has recommended Spencer Turbos in connection with their furnaces and ovens. A few recent installations are shown above.

Spencer Turbos have met the test of time—in years and in continuous service with a minimum of shut downs and maintenance costs. The simplicity of design with wide clearances, low peripheral speeds and only two bearings to lubricate is partly responsible. Other features are described in Bulletin No. 126-A illustrated below.

THE SPENCER TURBINE COMPANY

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494 A

Manufacturers of Turbo-Compressors and Heavy Duty Vacuum Cleaners

Personal Mention

Earle C. Smith

R. Carson Dalzell

EARLE C. SMITH, many times honored for his work in metallurgical and engineering fields, is now director of research, Republic Steel Corp., Cleveland, and will supervise Republic's new research laboratory to be built in Independence, Ohio. He will also continue as chief metallurgist for the company.

Earle Smith combines a vast theoretical knowledge with wide practical experience in the steel industry and an ability to handle men.

A graduate of Ohio State University, Mr. Smith joined Central Steel Co., a predecessor of Republic, in 1917 as chief inspector. He rose rapidly in the company and in 1932, when the organization merged with Republic, was named chief metallurgist of the entire corporation.

During World War II, he helped produce special steel for the miltary, and was a member of a three-man team sent to England to coordinate British and American steel efforts.

Mr. Smith has been accorded wide recognition for his work, including the Gold Medal Award in 1946 for outstanding service to the metals industry, the American Iron and Steel Institute Medal in 1940, and the Ohio State University Lamme Medal in 1948 for achievement in the field of engineering. In 1950 he presented the Campbell Memorial Lecture before the annual meeting of the Society.

R. CARSON DALZELL has been appointed chief of the engineering development branch, division of reactor development, U. S. Atomic Energy Commission, Washington, D. C. He brings to this position two characteristics he thinks are helpful: the ability to be a good listener and a strong curiosity about any technical or scientific field. These two traits have helped Dr. Dalzell accumulate an enormous technical background which is a major factor in making good engineering decisions on lines of research and development.

Educated at John Hopkins University and Harvard University, he spent many years with Revere Copper and Brass, Inc., in Baltimore, Detroit, Chicago and Rome, N. Y. His duties there were concerned with applied development, plant management and general management.

In 1950 he came to A.E.C. and has been directing the general materials and fuel development program of the division of reactor development, and consulting on other applications of materials in the general A.E.C. program. It was under Dr. Dalzell's guidance that zirconium and beryllium were brought from pilot plant to commercial production. He will now be in charge of all general development work in the division, excluding specific power reactor projects.

Since joining the Baltimore Chapter in 1937, Dr. Dalzell has been an active member. He served as chairman of the Baltimore Chapter and has held positions on various committees of the Detroit, Chicago and Washington Chapters. When he moved to Rome, N. Y. in 1945, he organized an chapter there and served as its first chairman.

Edward J. Korda, formerly associated with the Wright Aeronautical Div., Curtiss-Wright Corp., Wood-Ridge, N.J., is now associate professor of metallurgical engineering at Drexel Institute of Technology, Philadelphia.

Stuart R. Vandenberg has transferred to the atomic power equipment department, General Electric Co., San Jose, Calif., as a materials engineer. Mr. Vandenberg has worked successively in the Knolls Atomic Power Laboratory, Technical Recruiting Dept. and Large Steam Turbine Dept. at General Electric's Schenectady operations.

Earl T. Hayes is now assistant chief metallurgist, Bureau of Mines, Washington, D.C. For the past eight years, he was chief of the Bureau's branch of physical metallurgy, region I, in Albany, Ore., directing work on zirconium, hafnium, chromium and other rare metals.

Charles H. Fuchsman, until recently research group leader of Columbia-Southern Chemical Corp., Corpus Christi, Tex., has been named director of development for the Ferro Chemical Corp., Bedford, Ohio.

Frank Kiper, vice-president of Consolidated Foundries and Mfg. Co., Detroit, was elected president of Michigan Industries Co., a wholly owned subsidiary of Consolidated Foundries. Mr. Kiper will have direct responsibility for the five divisions of the newly organized company, composed of Michigan-Standard Alloy Casting Co., Misco Fabricators, M.S. Machine Products Co., WaiMet Alloys Co., and Western Foundry Co. **Roger F. Waindle**, formerly president of WaiMet Engineering Co., was also named president of WaiMet Alloys Co.

2,500,000

sink strainers couldn't be wrong

Strainer is made from [illegible] gauge x 7" Revere Leaded Brass Strip drawn to a depth of 2½".

MICHIGAN BRASS Company saw to that by using REVERE Leaded Brass Strip

Michigan Brass has a reputation for making only quality plumbing goods. So the material for their sink strainers had to be good to start with and remain consistently so over the years. After making over two and a half million strainers from Revere Leaded Brass Strip they tell us that not only has their quality for this item been consistent, but they also have realized certain savings in production.

Here's why they use Revere Leaded Brass for their strainers:

1. The inherent corrosion resistance of brass. 2. Its deep drawing characteristics (Photo at left above shows strainer after it has been blanked and drawn in progressive die). 3. Ease of machining large diameter threads with leaded brass. 4. The excellent surface that can be developed for chrome plating (Photo above right shows strainer after it has been trimmed, dimpled, threaded and plated). 5. The consistent uniformity and quality of Revere Leaded Brass Strip over the years.

These very same characteristics of Revere Leaded Brass Strip may be the very ones that could help you retain the quality of your product over the years . . . cut your production costs. Why not have a chat with a Revere TA (Technical Advisor) and see? It costs you nothing . . . may save you plenty.

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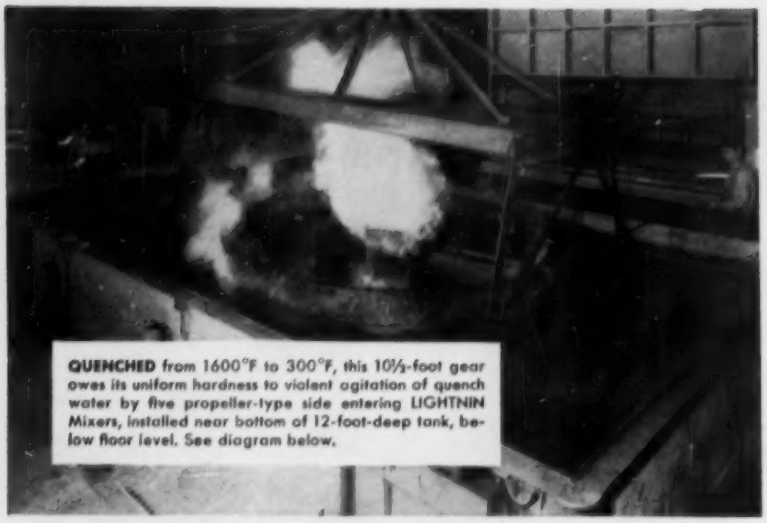


QUENCHED from 1600°F to 300°F, this 10½-foot gear owes its uniform hardness to violent agitation of quench water by five propeller-type side entering LIGHTNIN Mixers, installed near bottom of 12-foot-deep tank, below floor level. See diagram below.

No soft spots *in this* 7½-ton gear

How do you get uniform hardness in a cast steel gear weighing 7½ tons?

The Falk Corporation (Milwaukee) does it with this king-size water quench tank, equipped with five 25-horsepower propeller-type LIGHTNIN Mixers.

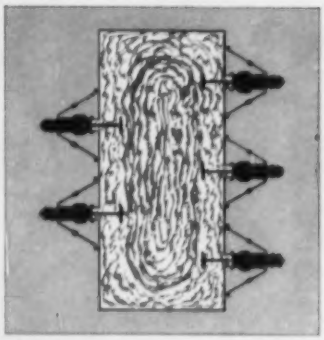
The gear is quenched at Wisconsin Steel Treating & Blasting Co. for The Falk Corporation, who engineered the process.

To speed heat extraction, the LIGHTNIN Mixers churn the water violently during quenching. The resulting turbulence constantly *wipes* and *wets* every square inch of the huge gear surface.

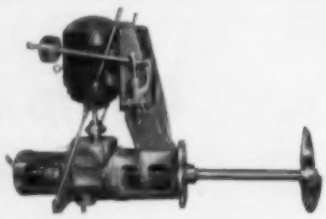
Temperature of the gear drops from 1600°F to 300°F—producing the desired hardness over the entire gear, which is 10½ feet in diameter.

"We are fully satisfied with LIGHTNIN Mixers for this important quenching operation," says Edward J. Wellauer, Falk's Assistant Chief Engineer. "The mixers were installed late in 1953 and have given us excellent results ever since."

Don't let size keep *you* from getting better physical properties, greater toughness in quenched parts. You can improve hardness uniformity, reduce or eliminate warpage and cracking, retreats and rejects—by quenching parts as small as a lock washer, as big as a 105mm gun barrel, with LIGHTNIN Mixers. Write us today for facts on LIGHTNINs that will give you the results you want.



UNIFORM TURBULENCE in bath wipes vapor film rapidly from entire surface of gear, for maximum liquid contact and best possible heat transfer conditions.



SIDE ENTERING unit is one of many LIGHTNIN types you can get, in sizes from ⅓ to 500 HP. You can use LIGHTNIN Mixers for standard quenching, martempering, austempering; for batch or continuous work; in new or existing quench tanks of any size and shape.

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Personals . . .

Theodore W. Bossert has assumed new duties as chief metallurgist for Aluminum Co. of America, Pittsburgh, and will head the metallurgical division of the operating department. Since 1951 Mr. Bossert has been serving as assistant chief metallurgist of the metal manufacturing division.

Charles F. Kettering was honored with an award from six engineering societies during the fall meeting of the American Institute of Electrical Engineers in Chicago. The award, which is called the Charles F. Kettering Medal, is sponsored by A.S.C.E., A.I.M.E., A.S.M.E., A.I.E.E., A.I.C.E., and S.A.E., and is being presented for the first time. It is expected that the award will be made annually to an outstanding engineer "for creative accomplishments for the benefit of mankind, including discovery, invention, improvement in designs or processes within the relationship of materials and energy". Mr. Kettering is a director and former vice-president of General Motors Co., Detroit, and former general manager of the General Motors Research Laboratories.

James A. Krimian has received a U.S. Civil Service appointment as a materials engineer assigned to the rubber and nonmetals section of the research and development division at the Detroit Arsenal. For the last two years Mr. Krimian was chemical engineer in the Packard Clipper Div. of Studebaker-Packard Corp., and prior to that was associated with the Murray Corp. of America, Detroit, for 21 years.

Harold C. Templeton has joined Alloy Steel Products Co., Linden, N.J., as chief metallurgist working on corrosion problems in application of stainless steel valves. Formerly he was chief metallurgist at the Lebanon Steel Foundry, Lebanon, Pa.

John F. Richards, formerly metallurgical engineer in the atomic energy division of Sylvania Electric Products, Inc., Bayside, N.Y., has been named associate scientist (metallurgy), materials section, research and advanced development division, Avco Mfg. Corp., Lawrence, Mass.

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Here's a fast, economical method of high-strength assembly utilizing Selas gas-fired automatic heat processing. Combining low first cost, minimum labor skills, high production capacity, consistent product quality . . . each Selas automatic brazing machine is custom-built to the customer's individual requirements. Yet, it is highly versatile, easily adjusted for different heat placement or time cycles.
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Send for new Bulletin "Production Brazing and Soldering" and reprint "Mechanical Heating Puts Brazing on the Production Line."
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Your choice of one or more pieces of literature which shed a light on the complicated problems of blast cleaning abrasives. No tricks, no strings, no obligation!

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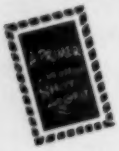

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This pamphlet suggests a simple control solution of blast cleaning operations. So simple an office boy can operate it—does away with "testing" and never interferes with your operations.

This literature will be sent to you with the compliments of *Controlled T Shot & Grit and Permabrasive Annealed Shot & Grit*—the abrasives that guarantee a savings* in writing and pay off in hard, cold cash money.

*10% in the case of Permabrasive, 15% in the case of Controlled T

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- ☐ "A Primer on the Use of Shot and Grit"
- ☐ "It's Triplets" (A Story of Palletizing)
- ☐ "Tired of Making Tests?"

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Cleveland, Ohio
THE WESTERN METAL ABRASIVES COMPANY
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Personals . . .

Charles H. Shelton was recently appointed chief metallurgist of the White Motor Co., Cleveland, in charge of all activities of White's metallurgical laboratory. For the past five years Mr. Shelton has been chief metallurgist for the Tyson Bearing Corp., Canton, Ohio, a subsidiary of SKF Industries, Inc., and before that was associated with the Park Drop Forge Co., Cleveland, and Timken Roller Bearing Co., Canton, Ohio.

Charles C. Eeles has been promoted to manager of industrial sales, Ohio Fuel Gas Co., Columbus, Ohio. Associated with Ohio Fuel since 1927, Mr. Eeles was formerly assistant manager of industrial sales.

George W. Klohr has been transferred to the Washington works of E. I. du Pont de Nemours & Co. as administrative assistant in the technical section manager's office. Prior to his transfer, Mr. Klohr held several supervisory positions in the technical section of the company's Belle, W.Va., plant, including that of materials coordinator for the polychemicals department. He will continue as consultant on materials of construction for the company.

Thomas A. Carr has been appointed supervisor of metallurgy and quality control for the Spring Div. of Crucible Steel Co. of America, Pittsburgh. Mr. Carr has been with the company since 1939.

Massoud Simnad has joined the General Atomic Div. of General Dynamics Corp., San Diego, Calif. His work will include research and development of new nuclear reactor designs. A native of Iran, Dr. Simnad was granted a Weston Fellowship from the American Electrochemical Society, and a guest fellowship at Carnegie Institute of Technology's Metals Research Laboratory in 1949. From 1950 until joining General Atomic, he was a staff member of the laboratory and a faculty member of the Institute.

Howard F. Brennan, formerly a representative for Loftus Engineering Corp., Pittsburgh, Pa., now represents Metalwash Machinery Corp., Elizabeth, N.J., in northern New Jersey.

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uniform in handling ease
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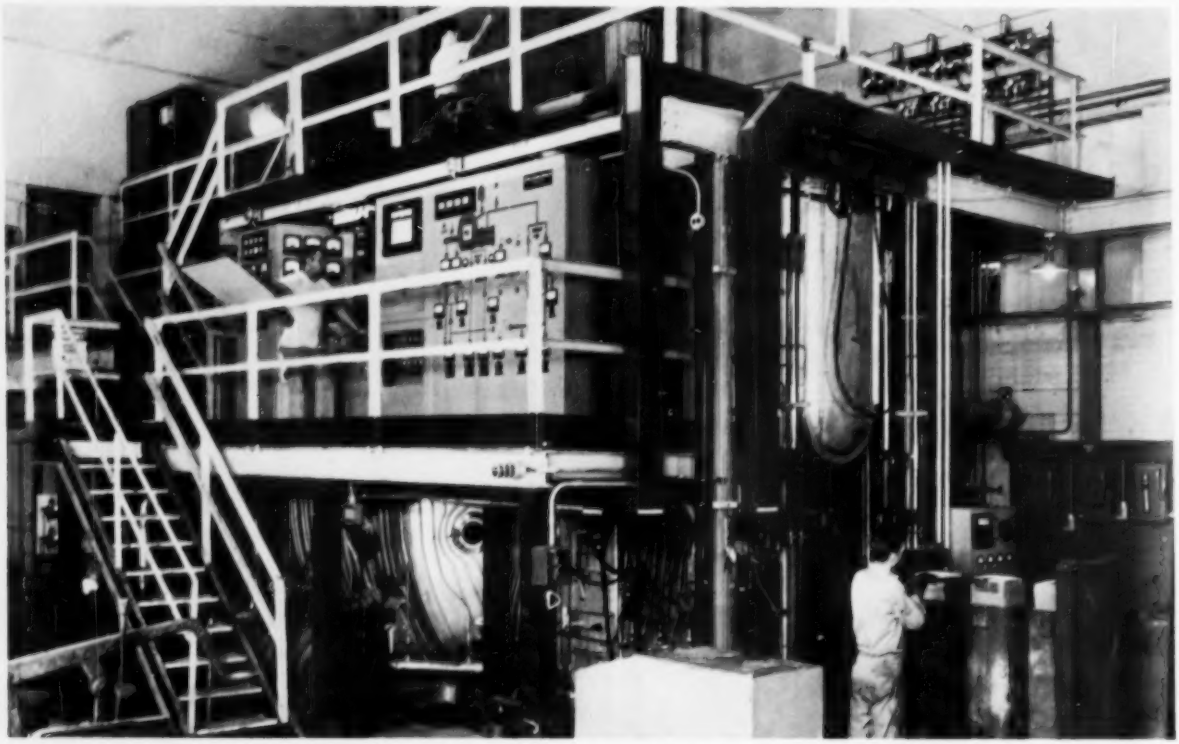
At Last! Proof That Vacuum Furnaces Have Grown Up



Two miles of wire and one-half mile of copper tubing were used in the construction of this vacuum furnace by National Research Corporation for Vacuum Metals Corporation, Syracuse, New York. Equipped with air locks and hydraulic controls, it permits casting and removing 3000 pound ingots without breaking vacuum. "Watch-dog" timers and interlocks guard against operator error and make the operation of this furnace almost automatic.

Facts About the Triumphant Performance of
The World's Largest High Vacuum Induction Furnace

This NRC unit, built for Vacuum Metals Corporation, set a new standard of performance for large high vacuum furnaces. Not only is it the world's largest and most automatic vacuum induction furnace, but it successfully produced a 2200 pound ingot *on the very first try*. It is today making melts up to 3000 pounds in a wide variety of alloys and ingot combinations.

From their own sad experience many vacuum melters agree that it is unusual for *any* vacuum furnace to perform properly, right from the start. It is unheard of for a "first-of-its-kind" furnace of such size and complexity. Among its pioneering features are operation of the induction coil at 800 volts, coaxial power leads, provision for flooding with argon in less than 11 seconds, pictorial control panel, and joy-stick controls.

You can expect completely satisfactory performance like this from any NRC vacuum furnace — large or small — induction, arc, or resistance. From the 4 pound NRC Model 2904B to production-sized furnaces, they all will give you maximum results with a minimum expenditure of man hours. That's because of what we've learned from building and operating more high vacuum furnaces than any other organization in the world. Send coupon below for more information.

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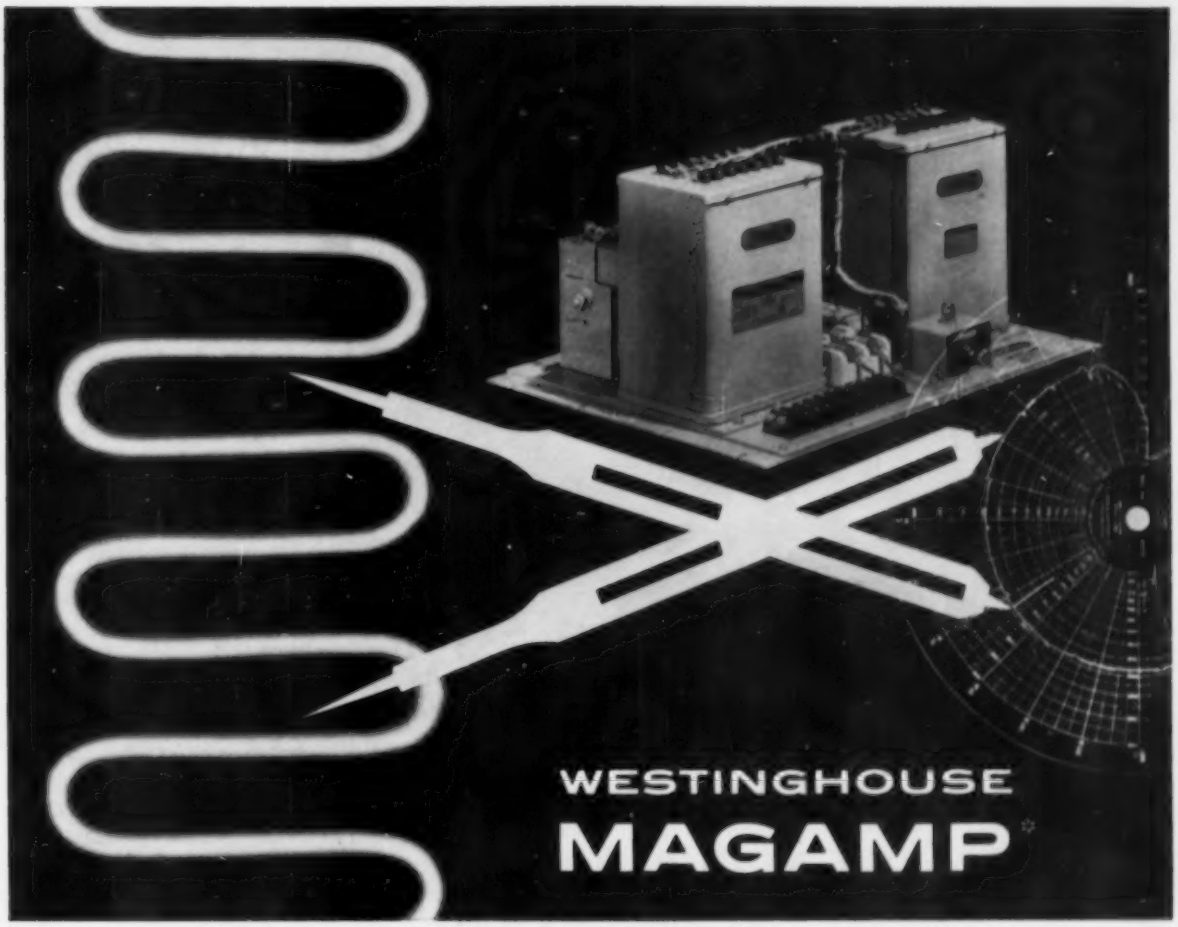

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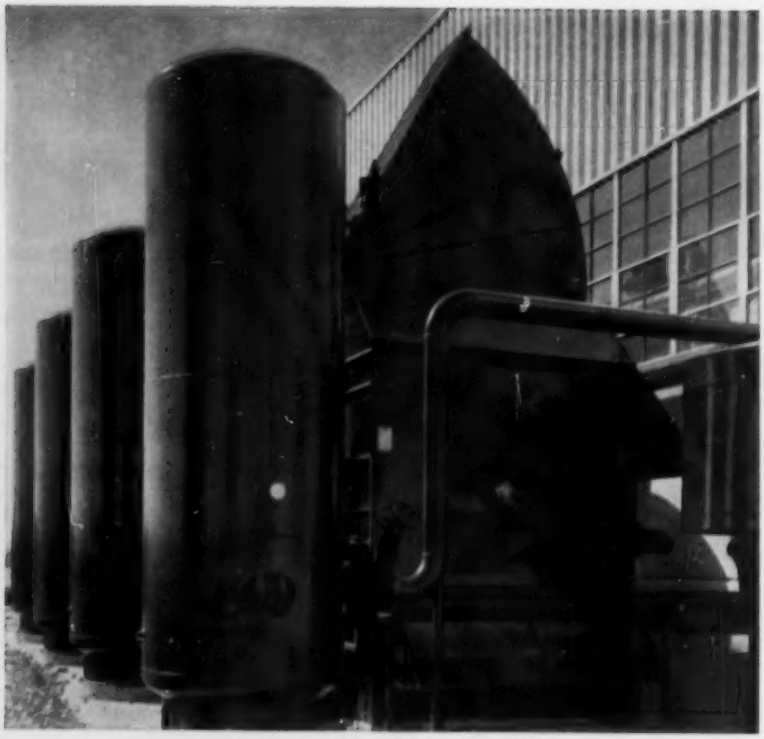

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Getting Drier Compressed Air

● Direct saving in the cost of cooling water saves the price of the Niagara Aero After Cooler (for compressed air or gas) in less than two years.

Extra, for no cost, the drier air gives you a better operation and lower costs in the use of all air-operated tools and machines, paint spraying, sand blasting or moisture-free air cleaning. Water saving also means less expense for piping, pumping, water treatment and water disposal, or you get the use of water elsewhere in your plant where it may be badly needed.

Niagara Aero After Cooler assures all these benefits because it cools compressed air or gas below the temperature of the surrounding atmosphere; there can be no further condensation in your air lines. It condenses the moisture by passing the air thru a coil on the surface of which water is evaporated, transferring the heat to the atmosphere. It is installed outdoors, protected from freezing in winter by the Niagara Balanced Wet Bulb Control.

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Personals . . .

William O. Schaffnit, a 1956 graduate of Grove City (Pa.) College, is now employed in operations engineering at the atomic energy division, Phillips Petroleum Co., Idaho Falls, Idaho. Phillips operates facilities for the Atomic Energy Commission at the National Reactor Testing Station in Idaho Falls.

C. W. Haynes, formerly associate professor at the University of Nebraska, is now senior research engineer at Autonetics, a division of North American Aviation, Inc., Downey, Calif.

Joachim Jacques Hauser and **James Myles Lommel** have been awarded International Nickel Co., Inc., Fellowships at Harvard for the 1956-57 academic year. These fellowships were established in 1955 with a five-year grant from Inco providing $4000 for fellowships and $4000 for use in the division of engineering and applied physics. A native of France, Mr. Hauser came to this country in 1953 and has studied and conducted research in the department of metallurgy at Rennselaer Polytechnic Institute. Mr. Lommel is a third year student in metallurgy working in solid-liquid reactions. Receiving his bachelor's and master's degrees from Illinois Institute of Technology, he has held the Hennen Jennings Scholarship and served as a teaching fellow at Harvard.

James L. Hickernell, a 1956 graduate of the Missouri School of Mines and Metallurgy, is now working as a metallurgist trainee for Reed Roller Bit Co., Houston, Tex. Mr. Hickernell has been associated with Hughes Tool Co., Houston, Tex., and is a veteran of the U.S. Navy.

Leonard E. Olds, formerly associated with Battelle Memorial Institute, is now a research metallurgist at the Denver Research Institute, University of Denver, Denver, Colo.

George Giles Beeker has joined the atomic power research laboratory at the Bettis Plant of Westinghouse Electric Corp. Mr. Beeker will work on the development of an atomic reactor for a large naval surface ship.

FAHRITE

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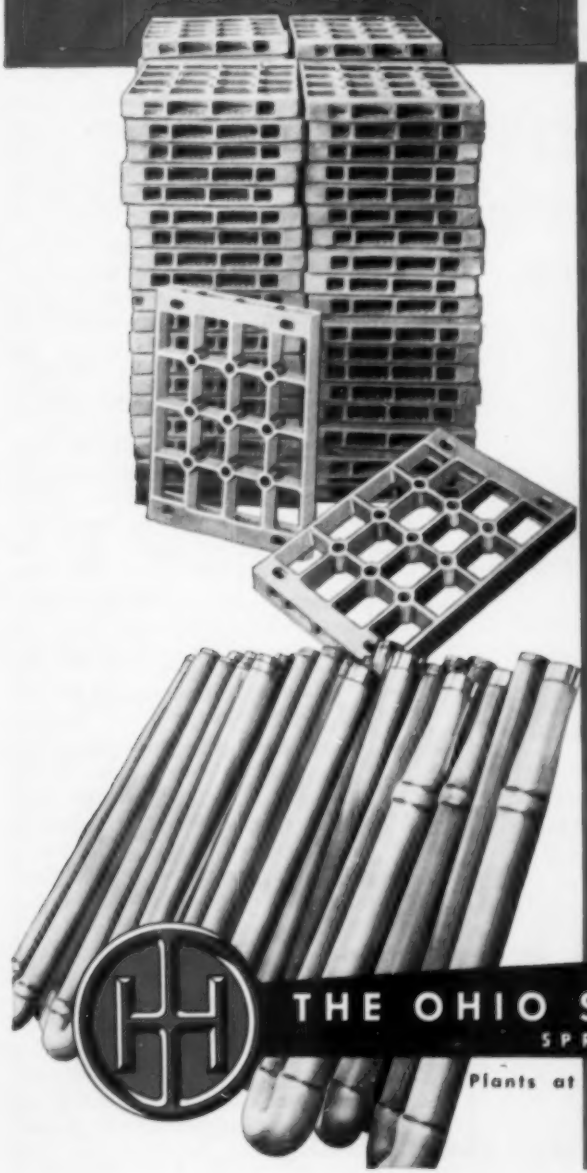

DESIGNED FOR SPECIFIC HEAT TREATING APPLICATIONS

Every heat treating operation has its own special casting requirements. Our engineers need only the facts about your particular heat treating operation to design and produce Fahrite castings with the correct characteristics to meet your problems.

Fahrite alloy castings are products of careful design, metallurgical and foundry control techniques—assuring sound, high tensile strength castings that resist thermal shock, stand up longer in service. There are grades of Fahrite to meet your exact operating conditions. A few of the many types of Fahrite castings made by Ohio Steel are:

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Personals . . .

Edward T. Bryand has joined the staff of the Portland Copper and Tank Works, Inc., South Portland, Me., in the capacity of supervisor, new products department. Prior to his recent position, Mr. Bryand was senior product engineer with Cleveland Graphite Bronze Co., Cleveland, for a year and before that was associated with the I.T.E. Circuit Breaker Co., Philadelphia.

F. R. Mitchell, Jr., was recently transferred from his post as a sales representative in the Springfield, Mass., area for the Carpenter Steel Co., Reading, Pa., to a territory in the Bridgeport, Conn., area.

Harvey A. Taylor, until recently employed in the technical department, titanium division, National Lead Co., South Amboy, N.J., is now an engineer in the aircraft nuclear propulsion department, General Electric Co., Idaho Falls, Idaho.

Herbert D. Cronin, formerly chief metallurgist for Morse Chain Co., Detroit, a division of Borg Warner Corp., has been named staff manufacturing engineer for the atomic power division, Westinghouse Electric Corp., Pittsburgh.

Stewart H. Kilmer has been named to the post of works manager of the Ambridge, Pa., plant, Spang-Chalfant Div., National Supply Co., Pittsburgh. Associated with the Ambridge plant since 1917, Mr. Kilmer was appointed general superintendent in 1949 and held this position until his recent promotion.

Matthew J. Donachie has accepted the post of works manager of Prentiss Wire Mills, Holyoke, Mass., a division of the H. K. Porter Co., Inc., Pittsburgh. The Prentiss operations were recently combined with those of the Riverside, N.J., Metal Div. and Mr. Donachie will coordinate the activities of both plants. He was previously associated with the Beryllium Corp., Reading, Pa., as president, chief metallurgist, and director of research and development.

Bernard J. Fischer, formerly assistant metallographist, is now experimental engineer with the Bethlehem Steel Co., Bethlehem, Pa.

10 to 100% faster pumping– with Stokes Ring-Jet diffusion pumps

Major advance in diffusion pump design increases capacities, shortens vacuum pumping cycles, permits operation against higher forepressures.

A COMPLETELY DIFFERENT design concept makes it possible for Stokes Ring-Jet diffusion and booster pumps to provide high vacuum pumping performance never before possible. Instead of a single jet cone, these pumps have a ring of jets. This construction increases cross-sectional area of the air path . . . retains short distance to the condensing surface.

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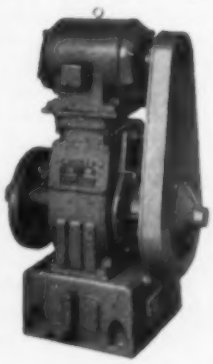
This increased efficiency cuts pumping cycles, permits use of smaller mechanical roughing pumps. It puts added value into many types of vacuum processing equipment . . . such as metallizers, vacuum furnaces and exhausting systems. Both diffusion and booster pumps are available in a range of sizes from 4 to 16 inches. For specifications, or for a consultation on your high vacuum application, call your nearest Stokes office. F. J. Stokes Machine Company, *Vacuum Pump Division*, 5508 Tabor Road, Philadelphia 20, Pa.

STOKES

MICROVAC mechanical pumps for high capacity, low maintenance



Ideal for use as roughing pumps, or as sole sources of vacuum in applications not requiring diffusion pump performance. New design features assure fast pumping, high capacity, efficiency over wide pressure range. Trouble-free operation is provided by fail-safe design, intake screen filters, double-spring exhaust valves. Write for Catalog 752 for complete information.

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Personals . . .

Col. Paul N. Gillon, commanding officer of the Office of Ordnance Research, Duke University, Durham, N.C., has retired from the U.S. Army in order to accept a position as manager of research with the Carborundum Co., Niagara Falls, N.Y.

Alexander H. d'Arcambal, past national president of ASM, has retired as president and general manager of Pratt & Whitney Co., West Hartford, Conn., and relinquished his position as chairman of the board of Potter & Johnson Co., Pawtucket, R.I., a Pratt & Whitney subsidiary. However, he will remain active in company affairs in a consulting capacity and as honorary chairman of the board of directors. Joining the Pratt & Whitney organization in 1919 as chief metallurgist, Mr. d'Arcambal rose rapidly through its executive ranks, becoming president and general manager of the company in 1954.

Edward J. Mullarkey ASM has been named technical director of Lead Industries Assoc., New York. He was formerly associated with Arma Corp., Brooklyn, N.Y., and a student at New York University.

D. A. Hanan ASM, formerly Detroit district manager of Peterson Steels, Inc., Union, N.J., has been promoted to the position of eastern district manager with headquarters at the home office.

Norman G. Bauman ASM and **Albert H. Fleitman** ASM have been named assistant supervising engineers for the engineering laboratories of the Crane Co., Detroit. The laboratories are located at the company's Chicago works. Mr. Bauman will work in engineering laboratories' metallurgical development program employing new metal-melting processes, while Mr. Fleitman will be connected with the development program for Crane heating products.

Peter V. Schneider ASM has been named staff metallurgist in product engineering at International Business Machine's product development laboratory in Endicott, N.Y. Mr. Schneider joined IBM in 1954 as an associate metallurgist and was assigned to the sintered metal laboratory.

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No electroplating--no mechanical finishing!

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NOW, FOR THE FIRST TIME you can get a brilliant, decorative finish directly on zinc die-cast parts . . . without mechanical finishing, without electroplating! The luster is provided by the *chemical polishing* action of new Iridite (Cast-Zinc-Brite) solution. Even surface blemishes, such as cold shuts, are brightened by this new process. No electrolysis. No special equipment. No specially trained personnel. Just a simple chemical dip for a few seconds and the job is done. And, this new Iridite has been *tested and proved* in production.

CORROSION RESISTANCE, TOO! New Iridite (Cast-Zinc-Brite) provides exceptional corrosion resistance for bright-type chromate finishes . . . also guards against blueing or darkening by eliminating zinc plate formerly required in bright chromate finishing of zinc die castings.

AS A BASE FOR ELECTROPLATING—Lower mechanical finishing costs are possible where plated finishes are *required* since the brightness provided by this new Iridite may be sufficient.

LET US SHOW YOU what Iridite (Cast-Zinc-Brite) can do for you. Send us at least a half-dozen typical zinc die-cast parts for FREE PROCESSING for your own tests and evaluation. Or, for immediate information, call in your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified 'phone book. *IMPORTANT: when you give us samples for test processing, please be sure to identify the alloy used.*

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Personals . . .

Daniel J. Martin, vice-president of Hughes Tool Co., Houston, Tex., has recently been elected to the board of directors of Trans World Airlines, Inc. Dr. Martin is also on the board of directors of Hughes Tool Co. and several of its affiliates.

Stephen G. Cupschalk has joined the atomic power research laboratory at the Bettis Plant of Westinghouse Electric Corp., Pittsburgh. Mr. Cupschalk will do engineering and development work on an atomic reactor for a large surface ship. Mr. Cupschalk, a 1955 graduate of Lehigh University, was studying in the graduate school at Lehigh before coming to Westinghouse.

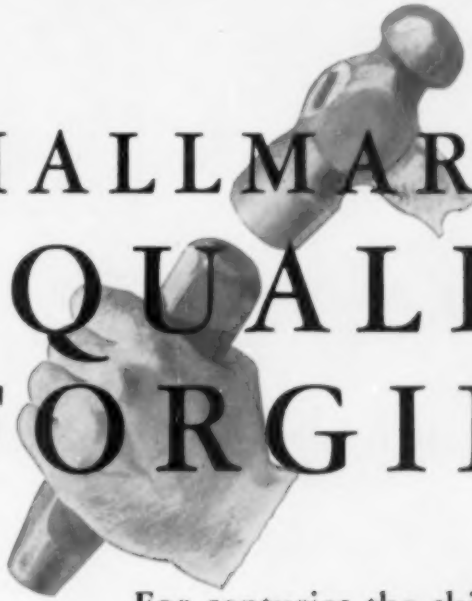
J. Herbert Hollomon, manager of the metallurgy and ceramics research department at General Electric Research Laboratory, Schenectady, N.Y., has been named as advisory editor for a new "Series on the Science and Technology of Materials", to be published by John Wiley & Sons, Inc., New York. This series of books will deal with the science and technology underlying the behavior, manufacture and the technical use of all important solid materials, and will be divided into three general areas: scientific understanding, applied science, and engineering materials and processes.

Homer C. Hueffed has joined the staff of the industrial engineering department of Leece-Neville Co., Cleveland, as manager. Mr. Hueffed most recently was superintendent of the company's Hamilton Ave. plant and prior to that was manager of the quality control department.

Donald R. Hill has returned to his position as laboratory metallurgist at the Columbia-Geneva Div., U.S. Steel, Geneva, Utah. Mr. Hill was transferred to the U.S. Steel Research Center, Monroesville, Pa., for one year.

Frederick H. Bremmer has been appointed superintendent, cutting department, at the Ambridge, Pa., plant, Spang-Chalfant Div., National Supply Co., Pittsburgh. Mr. Bremmer came to the Ambridge plant in 1929 and has been chief combustion engineer since 1945.

HALLMARK OF QUALITY FORGINGS



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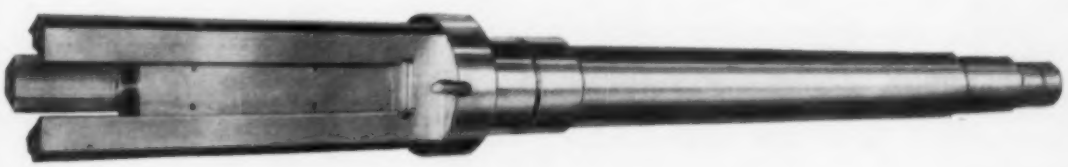
The trade-mark of the National Forge and Ordnance Company stamped on your forging is your guarantee that the forging has been carefully and skilfully made to meet your specifications exactly.



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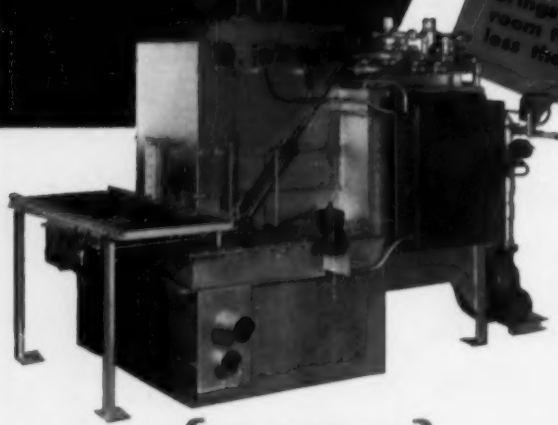
Brings 800 lb. load, room temp. to 1500°F less than 1 hr.

Model HA-400
Brings 400 lb. load, room temp. to 1500°F less than 1 hr.

Model HB-200
Brings 200 lb. load, room temp. to 1500°F less than 1 hr.



Model HA-400 Shown

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First WITH MECHANIZED, BATCH-TYPE, CONTROLLED ATMOSPHERE FURNACES

Personals . . .

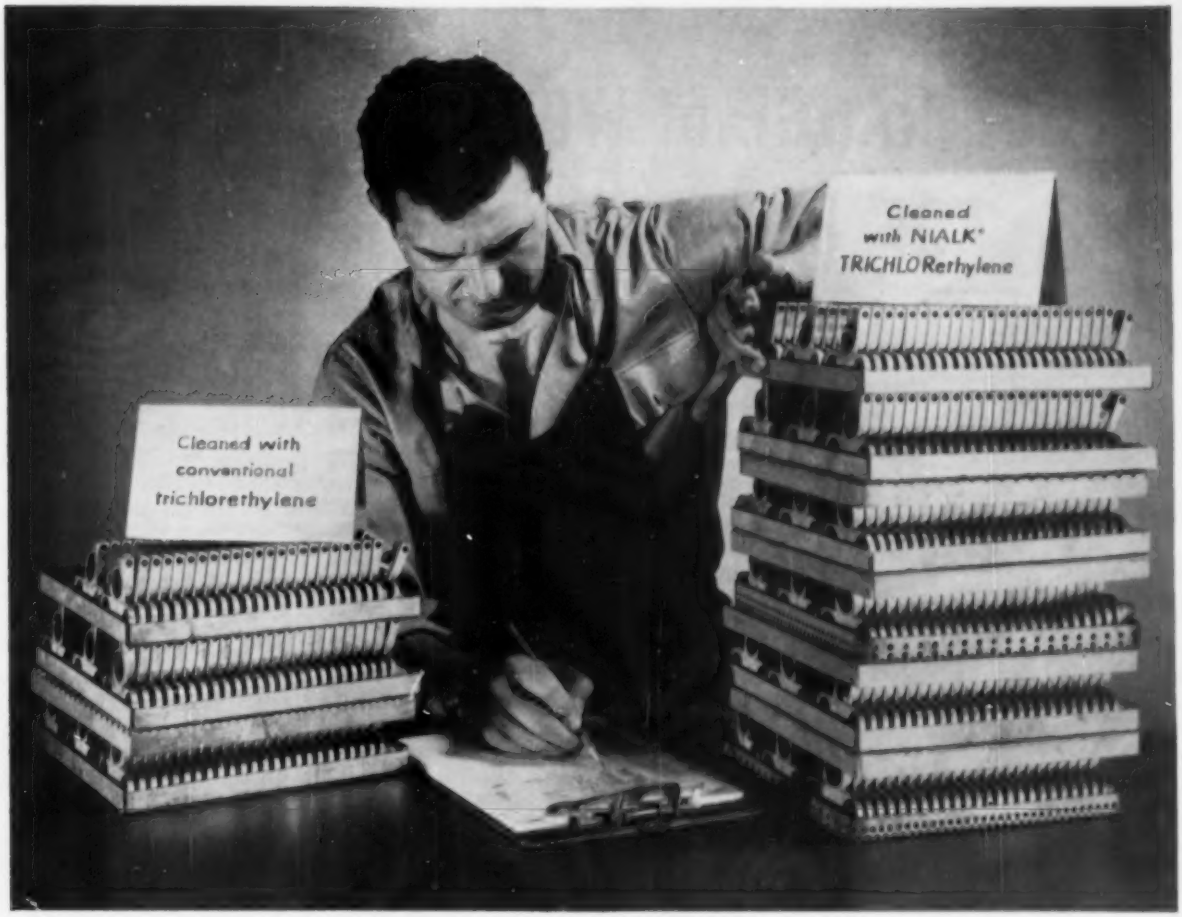
Clarence E. Jackson, research metallurgist at Metals Research Laboratories, Linde Air Products Co., Niagara Falls, N.Y., was awarded the Samuel Wylie Miller Memorial medal for outstanding research in the field of welding metallurgy at the fall meeting of the American Welding Society. Mr. Jackson has been associated with Linde Air Products Co. since 1946 and prior to that was head of the welding section of the Naval Research Laboratory, Washington, D.C.

George E. Linnert was also honored at the A.W.S. meeting. Mr. Linnert presented the Adams Honor Lecture, established in honor of the founder of A.W.S. and presented annually by a scientist or engineer who has made a new or distinctive development in the field of welding. Mr. Linnert is head of welding research in the research laboratories of Armco Steel Corp., Baltimore.

Paul R. Brucker and **Michael Zetz** have joined the metallurgical department of the Crucible Steel Co. of America's Midland, Pa., works. Associated with the company since 1935, Mr. Brucker will hold the post of division metallurgist in charge of flat rolled products. He has served Crucible as laboratory foreman, general supervisor and most recently as staff metallurgist of silicon steels.

Mr. Zetz has been appointed division metallurgist in charge of melting and bar products for Crucible Steel Co. Since joining the company in 1940, he has held the positions of laboratory technician and metallurgist, and prior to his present appointment was general supervisor of the flat products division.

R. Wayne Parcel has accepted a position as chief metallurgist with Dalmo Victor Co., Belmont, Calif., a division of Textron, Inc. In addition to his duties as company consultant on all metallurgical problems relating to materials and processes, Dr. Parcel will organize and administrate a metallurgical laboratory for the company. He was formerly supervisor of manufacturing with Rem-Cru Titanium, Inc., Midland, Pa.



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Personals . . .

William D. McMullen, a 1955 graduate of the University of Utah, has joined the Bettis Plant atomic power research laboratory, Westinghouse Electric Corp., Pittsburgh. His work will involve development of an atomic reactor for a large surface ship. Before joining Westinghouse, Mr. McMullen was studyding in Lehigh University's graduate school.

Donald E. Roda has been named supervisor of metallurgy in the research section, Rocketdyne Div., North American Aviation, Inc., Canoga Park, Calif. Before joining Rocketdyne, Mr. Roda was staff metallurgist for several plants of Plomb Tool Co. in the United States and Canada, and before that was chief metallurgist, Pacific Div., Bendix Aviation Corp., North Hollywood, Calif.

Thomas H. McCunn, formerly with General Electric Co., Schenectady, N.Y., is now research metallurgist in the research laboratory of Allegheny Ludlum Steel Corp., Brackenridge, Pa.

William H. Bailey has accepted a position as laboratory technician with the research and development laboratory of the Carborundum Co., Niagara Falls, N.Y. Prior to this appointment, he was an assistant heat treating foreman in the cold roll division of Crucible Steel Co. of America, Harrison, N.J.

Roland J. Ahern has been elected president and general manager of the Peck, Stow & Wilcox Co., Southington, Conn. Mr. Ahern has been chairman of the board of directors of the company for several years and will continue to serve in that capacity. In addition, he is also president and general manager of the parent company, Billings & Spencer Co., Hartford, Conn.

James M. Copeland was recently appointed manager of technical services in the Rochester, Minn., plant of International Business Machines Corp. Mr. Copeland joined the Endicott, N.Y., works as technical engineer in the metallurgical laboratory in 1951, and later served as associate metallurgist, project metallurgist and more recently as product metallurgist.

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Personals . . .

William C. Greenleaf has been added to the staff of U.S. Industrial Chemicals Co., a division of National Distillers Products Corp., New York, as manager of metals development. In his new position Mr. Greenleaf will be responsible for market development and sales of zirconium and titanium sponge produced in two new plants being built in Ashtabula, Ohio. For the last ten years Mr. Greenleaf has been affiliated with Allegheny Ludlum Steel Co., Pittsburgh.

A. E. Gurley and **C. R. Hannewald** were the recipients of the Metal Treating Institute Achievement Award at the annual meeting of the Institute in October. This award is made each year to the author of the most outstanding lecture presented at the annual spring meeting of the Institute or for any feature article appearing in *Metal Treating,* the Institute's magazine. Mr. Gurley and Mr. Hannewald, both affiliated with Chrysler Corp., Detroit, received this recognition for their article entitled "Development and Application of the Iso-Hardness Diagram" which appeared in the May-June 1956 issue of *Metal Treating.*

Eugene M. Smith has been advanced to the position of research administrator for the Lukens Steel Co., Coatesville, Pa. In this capacity, Mr. Smith will be responsible primarily for the development of new metallurgical and chemical products and processes. He joined the company's research division in 1954, after experience with Youngstown Sheet & Tube Co., Battelle Memorial Institute and Aluminum Co. of America.

Michael Hoch joined the staff of the University of Cincinnati as assistant professor of metallurgical engineering. Dr. Hoch was previously research associate with the Ohio State University Research Foundation, Columbus, Ohio.

Robert C. Bertossa, formerly head of the metallurgical research laboratory, Chicago Bridge and Iron Co., Birmingham, Ala., recently joined the metallurgy department of Stanford Research Institute, Menlo Park, Calif.

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Digests of Important Articles

Carburizing by Induction Heating

Digest of "Rapid Carburizing Using Heating by Induction", by A. D. Assonov, K. Z. Shepelyakovskii and P. A. Lankin, *Metallovedenie i Obrabotka Metallov*, No. 3, 1955, p. 39-50.

ONE DISADVANTAGE of conventional carburizing methods using either gaseous or solid carburizers is that about 10 hr. is required to obtain an adequate case. This article describes completely automatic equipment for carburizing and direct quenching which employs high-frequency induction heating and reduces the carburizing time to about 50 min.

The principal factor accounting for the greater speed of carburizing by this method is that the temperature used is 1975° F. instead of the usual 1700° F. Although Russian investigations from 1936 to 1938 indicated that electrical effects of direct current and high-frequency current greatly accelerated the rate of carburization, later work by Sadovskii and Spektor showed that the specific action of an electric current was too small to exert an appreciable influence on diffusion processes. Papers demonstrating the feasibility of high-temperature carburizing were published by Stroev during the war, and the present authors in 1954 described a commercial apparatus used for gas carburizing with induction heating at the Stalin automobile factory.

The equipment is shown in the drawing below. The gears to be carburized are fed in at *6* and are automatically moved to the left by the hydraulic cylinder, *8*. At *9*, an individual gear is raised by cylinder, *10*, to the bottom position in the stack of gears being heated. The inductor, *1*, that heats the gears is in a hermetically sealed casing, *2*, and is thermally insulated from the hot gears by the special ceramic lining, *3*. Carburizing gas is introduced at the bottom of the apparatus, *4*, and is burned at the top, *5*.

A gear is introduced at intervals of 1.5 to 3 min. so that each gear is carburized for 45 to 50 min. at 1975° F. The temperature is measured by a photoelectric pyrometer. The carburized gear at the top, *13*, is brought up to the top section, *11*, and is allowed to cool to about 1560° F. before being quenched at *12* and removed by the conveyor, *14*. The case depth produced by this treatment is from 0.032 to 0.040 in.

A problem encountered with this method is grain growth at the high

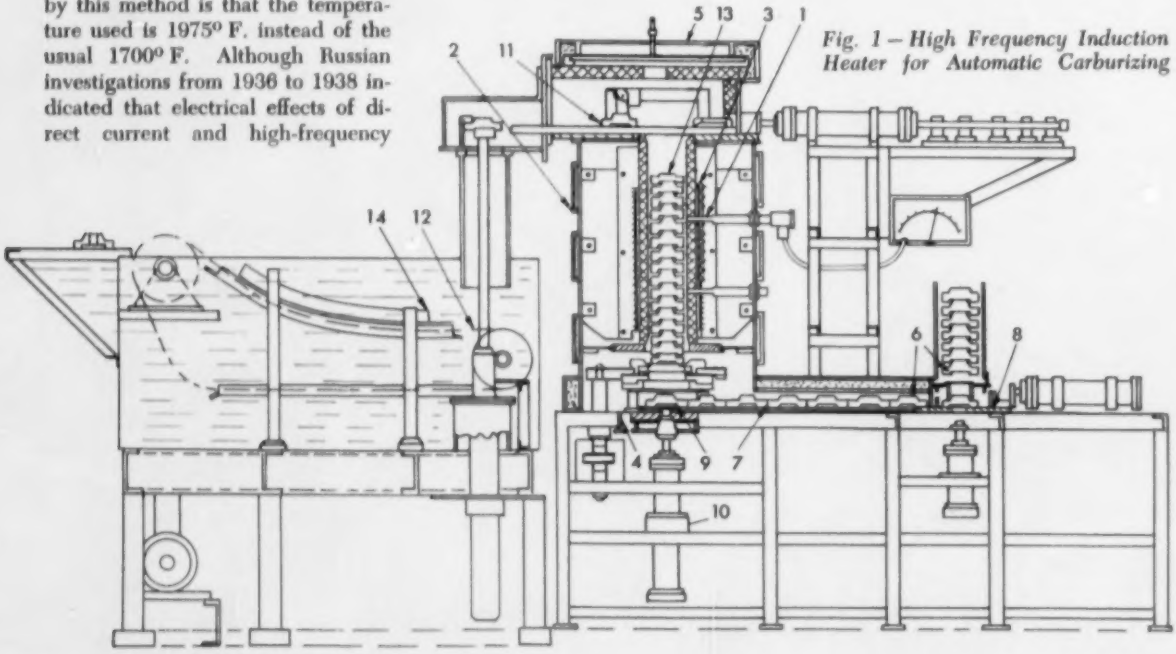

Fig. 1 – High Frequency Induction Heater for Automatic Carburizing

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WALLACE BARNES STEEL DIVISION

ASSOCIATED SPRING CORPORATION

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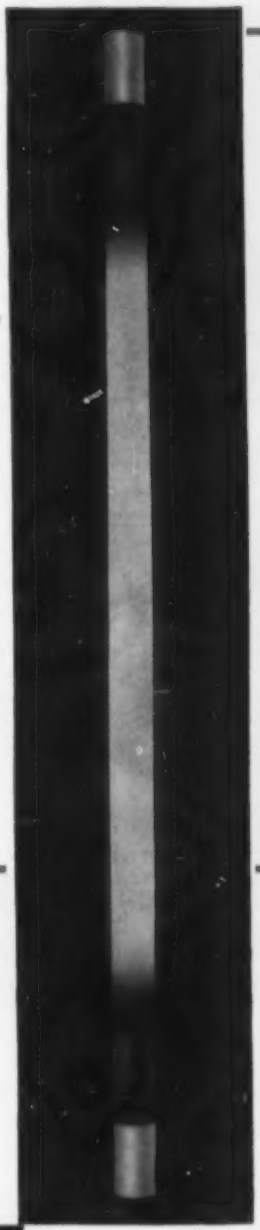

© This modern "Unit-Package" electric tube furnace operates at temperatures up to 2650°F. Designed and built by Burrell Corporation, Pittsburgh, Pa. — equipped with GLOBAR® Silicon Carbide Heating Elements.

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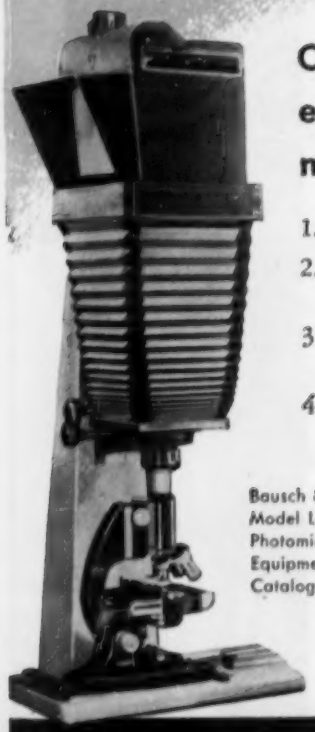

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Carburizing . . .

temperature employed. Fine-grained steels which had a grain size of A. S. T. M. 7 after carburizing at 1740° F. coarsened to a grain size of about 4 at 1920° F. and to about 2 at 2100° F. However, the mechanical properties of these steels, including impact strength at −80° F., were about the same after high-temperature carburizing as they were after normal carburizing. Other steels tested experienced more severe grain growth and these steels required an additional annealing cycle to refine the grain.

It was found that the addition of about 0.1% zirconium to carburizing steels helped prevent grain coarsening. Another refinement of the process permits a reduction in the amount of distortion in the final part by introducing a machining operation after carburizing. A different type of production machine is used for this purpose which incorporates a second inductor that anneals the gears at 1200° F. for about 30 to 40 min. The hardness is C-25 to 30.

The machine shown in Fig. 1 is a 60-kw. 2500-cycle model and has a production rate of about 250 lb. per hr. Production cost is only 75% that of the conventional process, and only 25% as much floor area is required for the same production rate.

Service results on gears produced by direct quenching from this high-temperature carburizing unit have been entirely satisfactory.

A. G. Guy

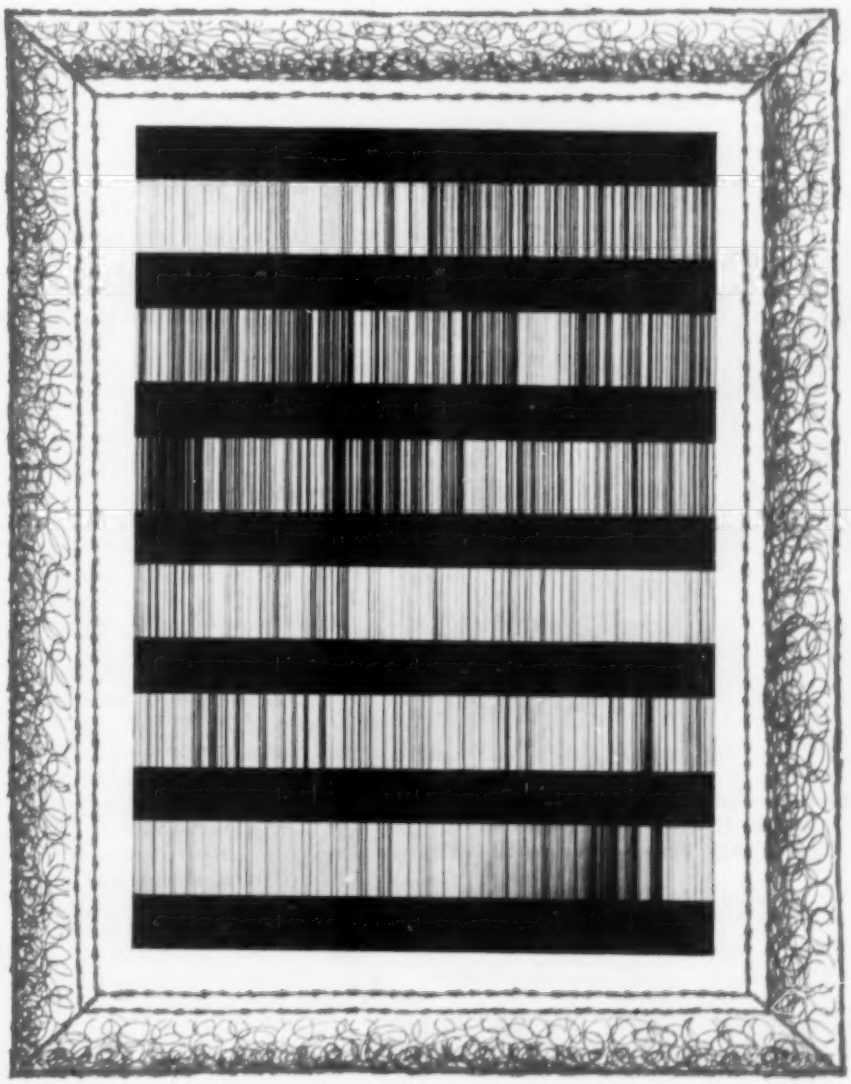
Continuous Casting of Tin Bronzes

Digest of "Experiments on the Semicontinuous Casting of Bronze", by E. C. Ellwood, J. C. Prytherch and E. F. Phelps, *Journal* of the (British) Institute of Metals, Vol. 84, p. 319.

Anyone interested in continuous casting will find many useful items in this paper. It is a logical supplement to the article on "Continuous Casting" by J. O. Smart in *Metal Progress* for October 1955, since it deals mainly with phosphor bronze – especially tubing.

Metal is continuously supplied through a tundish filled from a high-frequency furnace. The die is made

PORTRAIT OF A CHAMPION



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Continuous Casting . . .

of soft electro-graphite of fine grain. When casting 1.5-in. tubes with 0.25-in. walls of an alloy containing 10% tin and 0.5% phosphorus, production was at the rate of 15 in. per min.; 1-in. rods were also made at 12 in. per min. The machine is simple and relatively inexpensive.

The main difficulties encountered were "tin sweat", and friction betweeen the surface and the graphite die which caused the rods to break when the alloy was hot short. Tin sweat rings formed in the die about 0.75 in. below the bottom of the solidification front and adhered firmly to the graphite die – and to the rods as well. However, this did not affect the mechanical properties or soundness of the product, and the rings were removed by a very fine surface cut. The conditions necessary for a tin sweat are a gap for it to run into and a fusible constituent in the metal; the sweat persisted even when the metal was most carefully degassed.

Rod breakage increased with the speed of withdrawal. The only restraining force above the fracture point is the strength of the solidifying bronze, and when this is exceeded the hot rod breaks. The implication is that the bronze is "hot short" at the critical temperature and location. Unlike the continuous casting of aluminum, where the cast block must be supported, bronze requires a definite pull – as much as 400 lb. is frequently required.

There is considerable leeway as to casting temperature. For a bronze with 10% tin and 0.5% phosphorus this is 1750 to 2100° F. Metal in the melting furnace usually is between 1900 and 2000° F., and is at 1750° F. in the throat of the die. During operation the latter can satisfactorily go up to 1825° F.

In the casting of tubes a suitable tapered mandrel is attached to the bottom of the tundish, thus directing the flow of metal into a tubular shape. The paper contains data on taper and dimensions. The reviewer feels that the alloy chosen, namely high-phosphorus bronze, may easily prove the best for the casting practices described. Tin bronzes with less than 0.01% phosphorus might be expected to give trouble.

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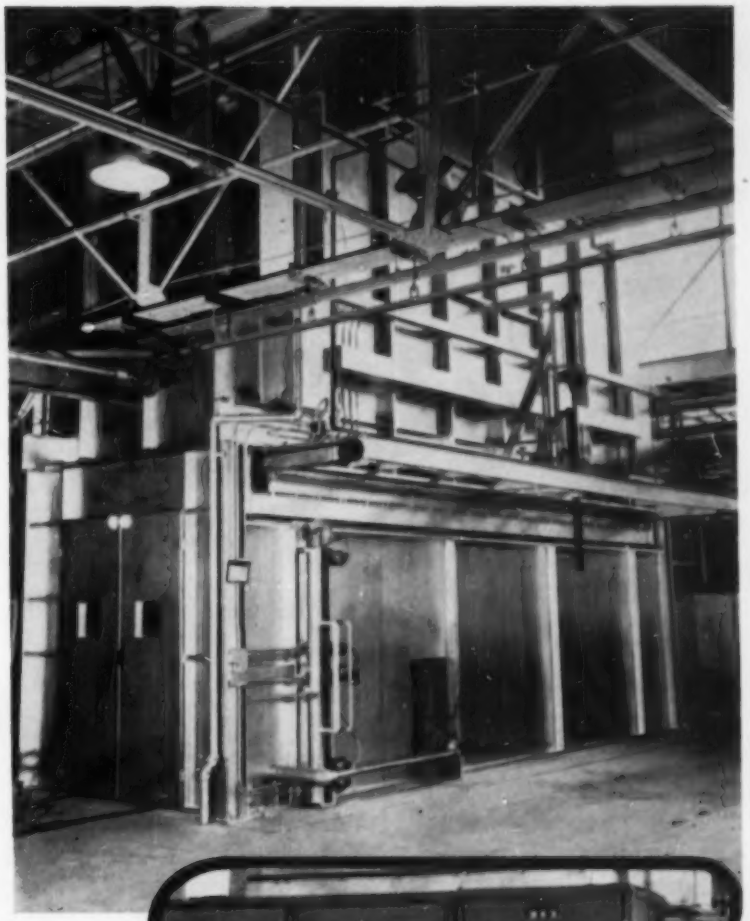

DESPATCH

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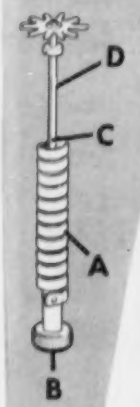

Here's how it works: The helical coil element of Chace Thermostatic Bimetal (A) is welded to a knurled brass plug (B) which is a press fit in the immersion tube. The free end (C) fits into the slotted end of the shaft (D) which is geared to the temperature indicator hand. The bending action of the bimetal in the coil causes the upper end to turn counter-clockwise as the temperature rises, thru rotating the shaft. The element is geared so that it rotates the indicator 180° between the range of 60° and 320° F.

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Continuous Casting . . .

coarse equi-axed and columnar crystals for alloys containing 10.5% tin and 2% zinc (as well as for 6.75% tin and 0.01% phosphorus) both cast at 6 in. per min. A finer structure appears in bars of 13.5% tin and 10.3% lead, and quite a uniform emulsion of 15% lead in a 5.5% tin bronze. This last is no doubt influenced by the fact that the casting temperature was 1775° F. – a low temperature for this alloy.

No major metallurgical defects such as shrinkage or gas cavities were found in any of the material by macro-examination, machining or fracturing. This indicates the excellent quality of the metal and is one of the great advantages of semicontinuous casting of these alloys. The microstructures show a good distribution of secondary constituents despite the coarseness of the macrostructure. A certain amount of microporosity was observed, insufficient to be ranked as a cause of rejection. Such porosity is more troublesome in low-tin alloys than in high-tin alloys. Fractures of the rods were smooth, silky and free from defects, the coarse grain not being reflected in the fractures in any way.

The mechanical properties are superior for straight tin bronzes in the range from 5.2 to 8.4% tin – the last mentioned giving over 50,000 psi. ultimate and 37% elongation.

HAROLD J. ROAST

High-Temperature Ceramic Coatings

Digest of "Ceramic Coatings and Processes — High Temperature Protection", by J. V. Long, presented at the Los Angeles Chapter Educational Program, Nov. 21, 1955, 19 p.

THE DEVELOPMENT of new power sources such as gas turbines, atomic reactors and the advent of supersonic flight have brought about the use of materials which will operate at elevated temperatures. Many ceramics, cermets and metals have been developed as coating materials for applications above 1800° F. in order to conserve strategic materials and add to the useful life of the base metal.

The ceramic coating of a metal is

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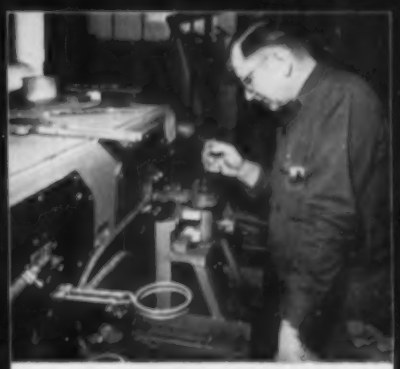

Jack & Heintz Inc. silver brazes over 25 different parts on this 15 KW, 10,000 cycle TOCCO machine.

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While costs dropped, production on the part zoomed —from 40 to 360 brazed assemblies per hour. Furthermore, rejects and scrap, formerly high, are now negligible.

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The part shown is just one of over 25 parts, large and small, which alert J & H engineers have converted from old-fashioned brazing methods to modern, automatic TOCCO. Overall brazing costs (TOCCO brazing versus former methods used) are down 75%—brazing speed, up 100%.

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Ceramic Coatings . . .

an art which requires control of the coating formula, coating manufacture, application and firing. The high-temperature ceramics are similar to porcelain enamels except that ceramic coatings are more refractory and heat resistant. These glass-like ceramic coatings have high strength, high hardness, good corrosion resistance and good thermal properties. Variations in analysis and manufacturing methods are employed to meet specific problems. The major problem in bonding ceramic to a base metal has been the low coefficient of expansion of the ceramic. This has been overcome by modification of the ceramic formula and the addition of cobalt, nickel or manganese oxide bonding agents. Coatings have been developed that protect carbon and low-alloy steels at elevated temperatures but some field failures have occurred because of the low strength of the low-carbon steel base.

There are many problems in coating alloy steel. Hydrogen which may be present in dissolved water in the frit causes blistering of the coating. The hydrogen may collect and the resultant pressure will cause fish-scaling or flaking of the coating. The elimination of moisture by using unfritted coatings or an inorganic solvent instead of water or by sandblasting instead of pickling will eliminate the effects of hydrogen.

During firing, oxygen combines with the carbon in the steel base to form carbon dioxide and carbon monoxide. These gases cause dimples and pinholes in the coating. The evolution of gas and surface oxidation can be reduced by firing in an inert atmosphere. The evolution of gas is also controlled by using special low-carbon enameling steels or steels which have the carbon stabilized by the addition of titanium.

Many laboratory tests have been developed to determine the properties of the coatings. Rough tests are generally used to make the initial separation between satisfactory and unsatisfactory properties. These tests include impact, thermal shock, burning and bending tests. More refined tests such as dynamic heating and continuous heating tests are also made. Alternate condensation and drying tests, solubility tests, tensile tests and fatigue tests may also be employed. Field tests with the cooperation of the customer are frequently made to confirm or check the laboratory findings.

The successful application of a high-temperature ceramic coating is dependent on correct processing and cleanliness. The coating will spall if the part to be coated is not entirely free of grease, oil, fingermarks and other foreign material. Parts to be coated should be cleaned by vapor degreasing and sandblasting.

Some of the limitations of ceramic coatings may be overcome with cermet coatings which combine the high-temperature properties of the ceramic and the ductility of the metal. Aluminum coatings have also been used to decrease the oxidation of metals at elevated temperatures. Aluminum coatings may be applied by calorizing, plating, spraying, cladding or casting. These coatings have excellent erosion resistance and good resistance to thermal shock, mechanical shock, corrosion and oxidation.

R. E. Lochen

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Evaluation of Metal Cutting

Digest of "Metal-Cutting Evaluation", by F. J. Daasch, American Society of Tool Engineers Preprint 24T19, 1956.

FIFTY YEARS of metal-cutting research have served to emphasize the soundness of basic principles enunciated in the famous paper by Frederick W. Taylor, "On the Art of Metal Cutting", presented before the A.S.M.E. in December 1906. The variables which affect production machining operations and laboratory experiments remain much the same and can be summarized as follows: (*a*) the type, condition and rigidity of machine tools, (*b*) the composition and condition of the work material, (*c*) the composition of the cutting tools, (*d*) the kind of cutting fluids used, and (*e*) the conditions of the cut.

How to reconcile these variables in any broad program concerned with evaluation of metal-cutting operations is no simple task. Much of the work in this field has been highly theoretical and at present there are still no definite standards of measurement applicable to all types of machining setups. However, most methods of studying metal cutting are based on one or more of the following four factors:

1. Life of the cutting tool.
2. Cutting tool forces.
3. Surface quality of the finished work.
4. Power consumed in machining.

The relative importance of the methods depends upon what arbitrary basis of measurement has been adopted as a standard.

Tool life generally is studied in accordance with the basic relationship that exists between cutting speed and tool life, that is, $VT^n = C$, where V is cutting speed in ft. per min., T is the tool life in minutes and C is a constant. Researchers need to know more about the fundamentals of this relationship and of the values for the constant.

A worthy contribution has been made to machining theory through the study of chip formation and the tool force system. Measurement of tool forces with the aid of dynamometers is of primary importance since it is closely related to previously listed variables such as work materials, tool shape and machine rigidity.

Further work on the method based upon power consumption appears to offer few attractions. Likewise, surface quality as an avenue of study seems to have doubtful possibilities, primarily because it is necessary to separate the effect of machining on the surface from the effect of metallurgical structure.

A new apparatus developed to simplify the selection of metal-cutting conditions has been provided commercially in the form of an electric analog computer. It combines in a portable self-powered unit, a system of numerical readings and variables, and solves for any one of 14 variables when fed information on 13. It will also consider five variables which affect horsepower requirements and provide information on one if supplied the other four. These are the variables: unit horsepower,

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Engineers

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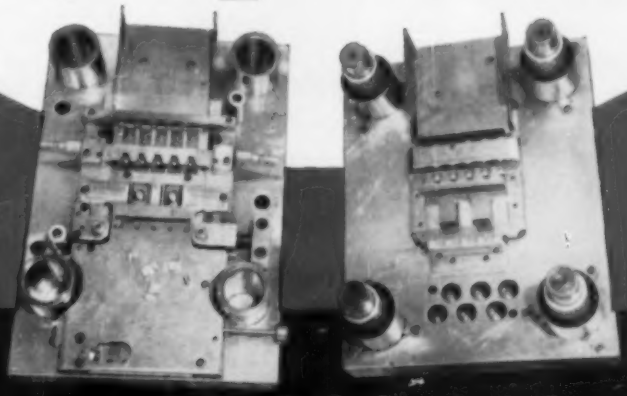

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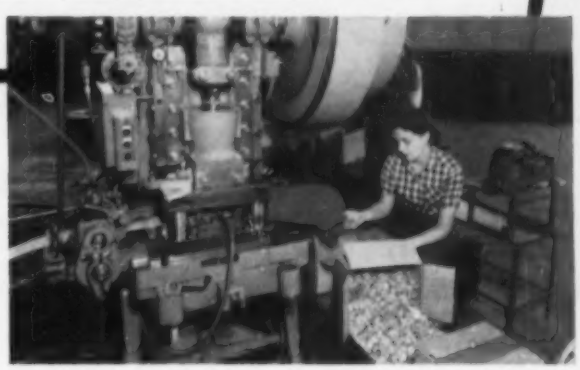

1 Excellent wear resistance of Olympic FM extended the normal life of the die.

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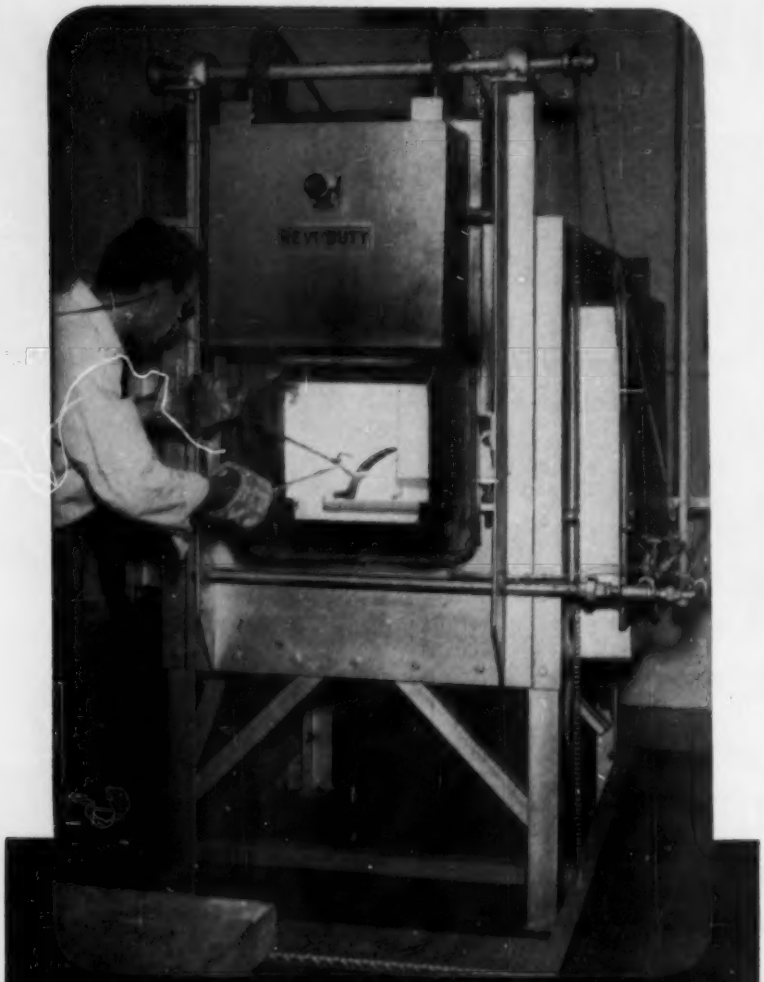

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Metal Cutting . . .

work material, microstructure, surface condition, hardness, cutting fluid, tool material, feed, flank wear land, tool profile, type of tool, number of teeth, cutting speed and the tool life.

Although metal-cutting research has progressed notably, the practicing individual has an urgent need for a better method of interpreting metal-cutting phenomena so that he can apply it accurately to a manufacturing operation.

ARTHUR H. ALLEN

New Uses for Tin

Digest of "An Old Metal Finds New Uses", by Herbert E. Hirschland, presented at a meeting of the Commercial Chemical Development Assoc., May 1956.

TIN WAS USED by man as long ago as 3500 B.C. The observation that this soft metal could impart considerable hardness to copper led to an early demand for tin.

New uses for tin are still being developed. A number of these, particularly in various chemical fields, are reviewed.

The consumption of tin has fluctuated considerably over the years due chiefly to two causes – the lack of domestic sources of tin and the unstable price picture. Both of these are gradually being brought under better control.

The major uses of tin in the United States are tin plate, copper-base alloys, solder, babbitt and chemicals. Tin has a number of desirable properties which favor its use in the above applications. Foremost among these is its nontoxic nature which permits widespread use as a coating for food containers and food-handling equipment. This has also led to a demand for the chemicals used in the tin-plating industry, such as stannous sulphate, stannous chloride, sodium stannate and potassium stannate.

Also of importance is the softness of metallic tin which has led to its use as a lubricating film on aluminum automotive pistons and as a major constituent in bearing alloys. The low melting point of tin accounts for its use in soft solders.

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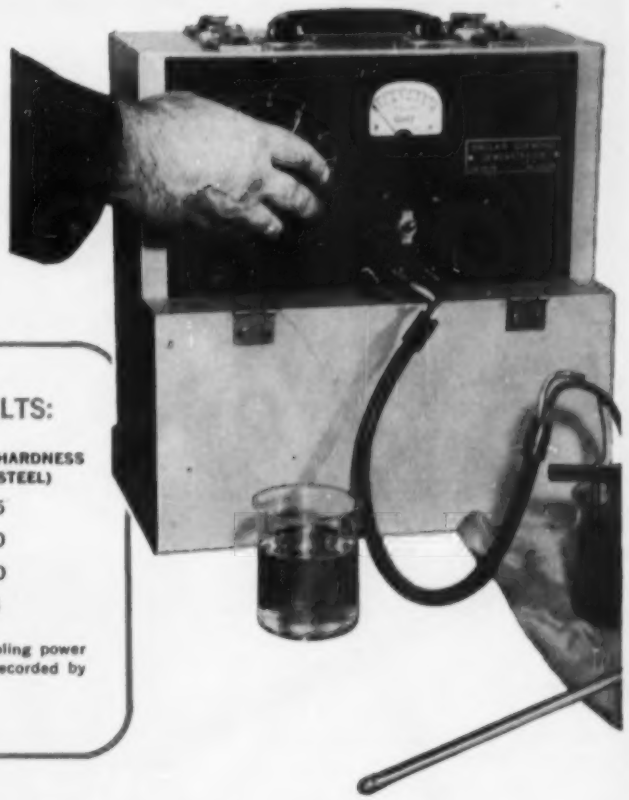

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Competitive Oil B	729	39.0
Competitive Oil C	1024	41.0
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*Based on a recognized formula for determining relative cooling power value. Measured as the square of the current (I^2max.) as recorded by Quenchol Demonstrator.

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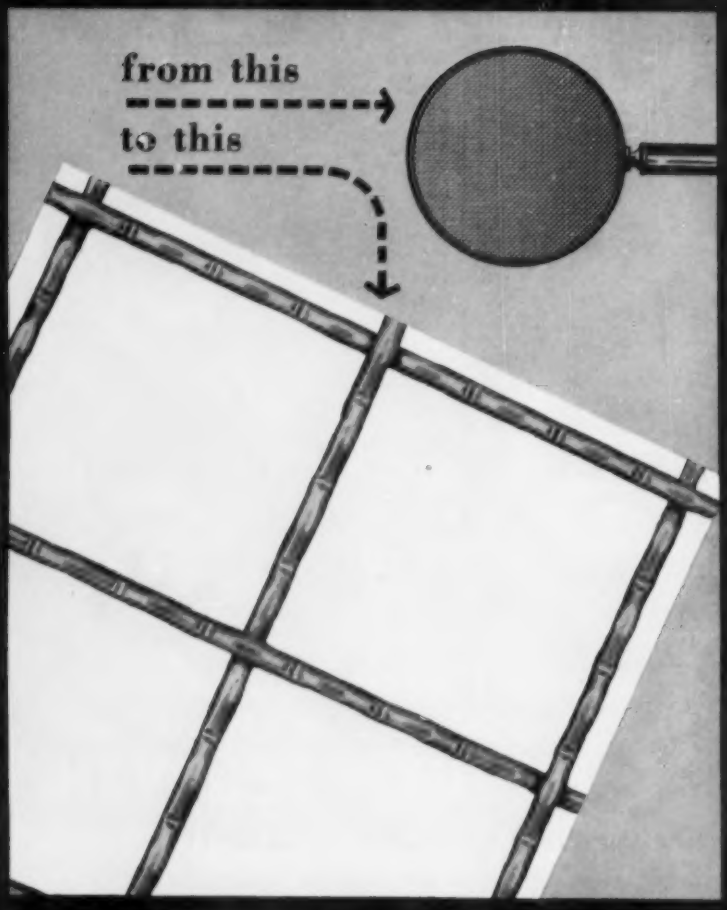

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Uses for Tin . . .

ceramic glazes, the chief applications of tin chemicals are as stabilizers. For example, tin tetrachloride is used to stabilize perfumes in soaps, stannous chloride to stabilize lead chromate-base paper colors, and sodium stannate to stabilize hydrogen peroxide. The stabilizing influence of tin has long been known. It was used as one of the ingredients in dyes made by several ancient civilizations.

More recent applications include the use of bismuth stannate to stabilize the capacitance of ceramic capacitors against temperature fluctuations, and the use of organotin chemicals to stabilize polyvinyl chloride plastics against the effects of heat and ultraviolet light. An application in the medicinal field which is receiving increasing attention is the use of stannous fluoride in dentifrices.

Various tin chemicals are also finding application as fungicides and bactericides. Tributyl tin oxide, for example, is used to control slimes in the pulp and paper industry and in addition it provides mildew resistance to papers and boxboard.

D. N. WILLIAMS

Aluminum Powder Metal Parts

Digest of "Aluminum Powder Metallurgy Products", by J. P. Lyle, Jr., presented at the 1956 meeting of the Metal Powder Association.

CONSIDERABLE development work has been carried out both in the United States and in Europe to evaluate the Swiss discovery that wrought aluminum made by powder metallurgical techniques has better elevated-temperature properties than the best of the wrought aluminum alloys. The advantages are a result of the presence of aluminum oxide in discrete uniformly dispersed particles which act to prevent slip. This phenomenon is much the same as that exhibited by precipitation hardening alloys but since the oxide particles are insoluble in the aluminum, they cannot redissolve at elevated temperatures. Such materials, therefore, are more stable at

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Aluminum Powder . . .

elevated temperatures than the heat treatable alloys.

Two APM (aluminum powder metallurgy) alloys, M 257 and M 276, are compared to three wrought high-temperature aluminum alloys, 2024-T 4, 2618-T 61 and X 2219-T 6. At 400° F., the ultimate tensile strength and yield strength of the APM alloys are lower than those of the three wrought alloys. Between 400 and 600° F., however, both APM products are stronger than the conventional alloys. At 1000° F., the APM alloys are stronger than X 2219-T 6 at 700° F. The elongation of the APM alloys is less than that of the conventional alloys and decreases with increasing temperature which is just the reverse of the behavior of conventional materials. The short-time tensile properties of the APM alloys are relatively unaffected by time at temperature prior to testing. This is not true of the conventional alloys which show appreciable decrease in strength after heating at temperature for extended periods of time.

The density of the APM alloys is somewhat less than the conventional alloys since the density of aluminum oxide is lower than the density of most alloying constituents in conventional alloys. The electrical and thermal conductivity of the APM alloys is, in general, somewhat higher than that of conventional aluminum alloys. This is a distinct advantage in those applications where good elevated-temperature strength and good thermal conductivity are required. The coefficient of thermal expansion of the APM alloys is somewhat lower than that of the conventional alloys.

Since alloy M 257 is more ductile than M 276, more emphasis has been placed on this alloy as far as fabrication into intricate shapes is concerned, even though it is not quite as good as far as elevated-temperature strength is concerned. Hollow extruded shapes and solid shapes with irregular contours have been successfully extruded. Die forgings have been produced, including a compressor disk approximately 21 in. in diameter and weighing about 33 lb. Various types of aircraft fittings, fan blades and compressor blades have also been forged from this material. Extruded tubing, impact extrusions and headed rivets and bolts are among the many types of parts that have been fabricated from alloy M 257. Sheet is rolled in commercial range of thicknesses in widths up to 48 in. and lengths up to 144 in.

Flash welding gives high-strength joints in M 257 at both room and elevated temperature. Spot welding has been partially successful. Fusion methods of welding have resulted in some porosity. The joints are, of course, no stronger than the filler material which is not as strong as the base material at high temperature.

The powder metallurgy alloys can be electroplated. Both hard chromium plate and silver plate have been applied to these materials. They can be anodized, although information to date indicates that higher voltages are required than for anodizing the conventional alloys.

A. S. Doty

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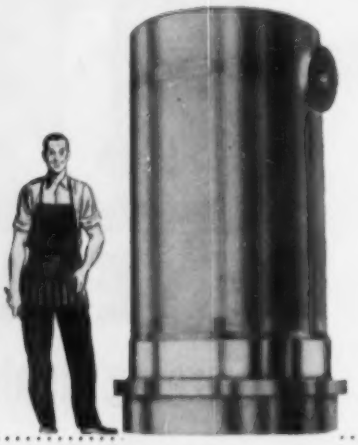

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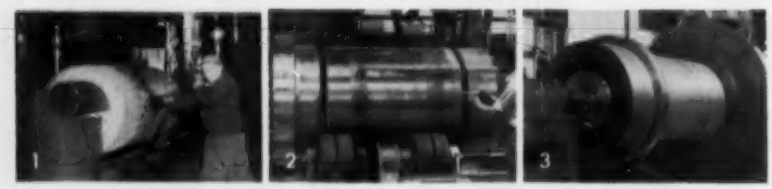

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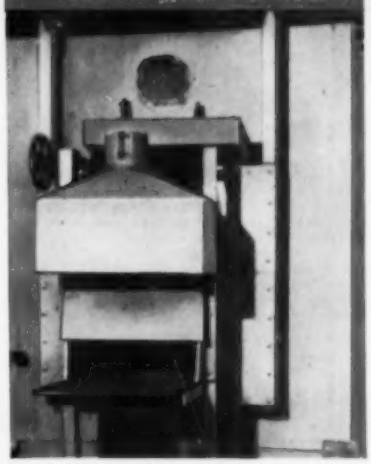

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Canton Connecticut

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dyna-trol ELECTRIC FURNACES

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
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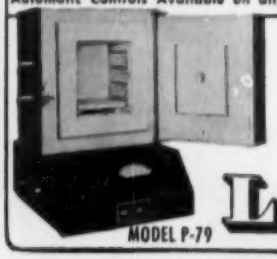
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models



- Infinite zone temperature control.
- Zone temperature indication by Pyrometer Selector Switch.
- Automatic hold and cut-off instrument available.
- Patented element holders.
- Infinite variety of time-temperature curves obtainable.
- Rugged construction. Highest quality insulation used

OVER 40 STANDARD MODELS • WRITE FOR LITERATURE

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INDUSTRIAL DIVISION
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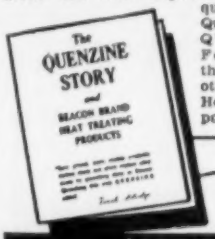
Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



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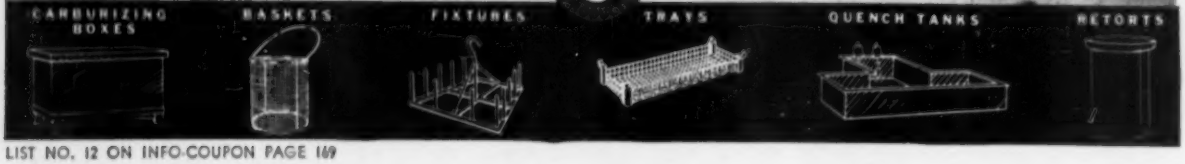

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ON YOUR BUFFING FIXTURES

when they can be *FUSECOATED* to last up to a year or more? We specialize in protective coatings for fixtures of all kinds and would like to add your name to our long list of regular customers.

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for our general information folder or send sample fixture or drawing of same to be FUSECOATED.

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Grade "B"

FERROUS METAL PROCESSING

Eliminates . . .

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Write for free sample and brochure Specify Grade "B"

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MAGNESIUM

your comprehensive independent mill source of magnesium alloy

Tubes • Rods • Shapes • Bars

Hollow Extrusions • Plate • Sheet

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Sales Office

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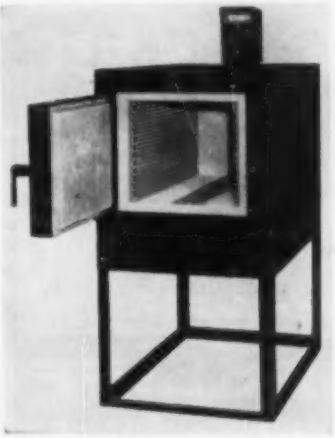

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Furnace Size	2000°	2300°
6x 6x12"	$ 500.00	$ 600.00
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Custom-made for your specific material removal problems

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Cutting and Surfacing concrete granite, and marble

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MANHATTAN RUBBER DIVISION

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Test our Service, Quality and Price by sending us a Sample Order.

Literature available — no obligation!

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ANY SIZE AND SHAPE • ANY DUCTILE METAL

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SOUTHPORT • CONNECTICUT

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Grade "C-W-25"

Non-flammable
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Aqueous Oily Film
Protects Ferrous Parts
for Long Periods
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Sel-Rex Precious Metals, Inc.

Precious Metal Processes FOR INDUSTRIAL APPLICATIONS

Developed *specifically* for industrial application, Sel-Rex Precious Metals offer many advantages over conventional processes. *One gram* of Sel-Rex BRIGHT GOLD, for example, *does the job of 2 grams* of regular 24 K. gold, because the deposits are more dense and twice as hard. Gives mirror bright finish directly from the bath, regardless of thickness requirements — eliminates costly scratch brushing, buffing and burnishing.

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• Hairpin Hooks • Sheet Crates
• Steam Jets • Chain
• Mechanical Bar, Tube and Coil Picklers

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SAVE TIME and TROUBLE

Eliminate the Tedious Microscopic Measurements of the Indentations.

Use Gries REFLEX Machines with Carl Zeiss Automatic Projection System

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SINCE 1923

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CIRCO VAPOR DEGREASERS—large or small—automatic or manual operation

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FREE! Write for 32-page CIRCO Degreasing Manual

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OVER 40,000 IN USE

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SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

MAGNETIC ANALYSIS SPECIAL EQUIPMENT

Electronic Equipment for non-destructive production inspection of both non-magnetic stainless and high temperature steel bars and tubing—seamless or welded—as well as non-ferrous bars and tubing. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed 200 ft. per minute.

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Electrical Equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

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Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

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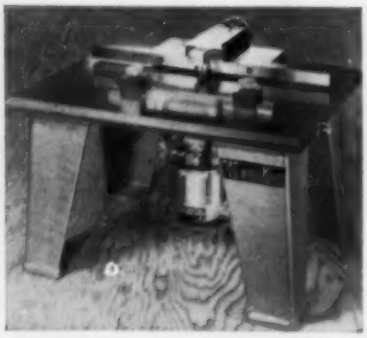
Patent Pending

Accurate tensile specimens machined from sheet and plate materials .0005 to .500 inch *in less than three minutes*



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Copper—Steel—Aluminum
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FOUR MODELS NOW AVAILABLE

Capacities to .125", .250", & .500"

SIEBURG INDUSTRIES

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HORSE PLAIN ROAD • NEW BRITAIN, CONN.

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Impressor

for quick, on-the-spot hardness testing of non-ferrous metals and plastics

Simple to operate . . . gives an instant, dependable measure of hardness. Operates on principle of forcing a spring-loaded indenter into the surface with the amount of penetration registering on a dial indicator. Can be used in any position . . . tamperproof . . . compact . . . rugged, yet weighs only 12 oz. Thousands used by industry. Write today for complete details.

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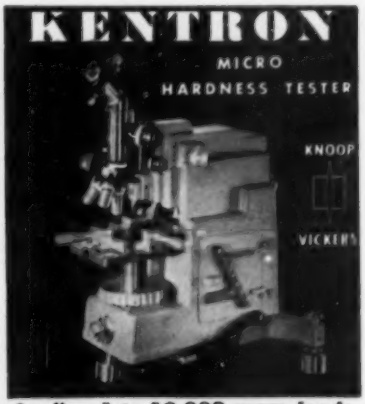

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The Torsion Balance Company

CLIFTON NEW JERSEY

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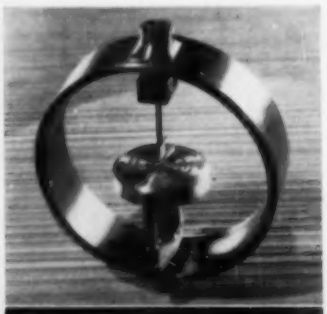

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National Bureau of Standards Certified . . . Available in both compression and tension types.

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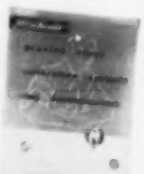

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"World Leader in Precision Calibration"

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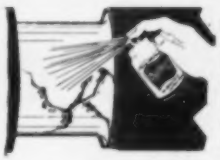
DYELINE INSPECTION PROCESS



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No solvent required—water removes Dyeline immediately.

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ZIP BELT LUBE—Prolongs belt life, promotes safety and speed.

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Rapid, Accurate, Non-Destructive

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Portable Thickness Testers for ranges from 0.020" to 4" or 0.060" to 12" of steel; accuracy up to 1.0%.

Detect Laminar Flaws and Lack of Bond

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PHOSPHOR BRONZE — ALUMINUM
OTHER NON-FERROUS

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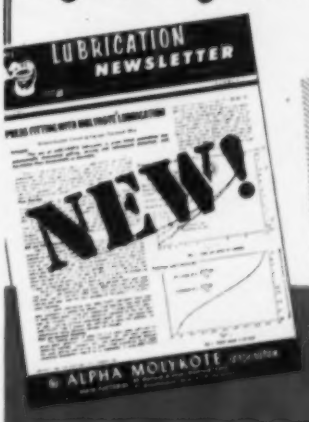

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EXTREME PRESSURE?
EXTREME HEAT?

the answer is

(Molybdenum Disulfide)

THE ULTIMATE LUBRICANT FOR EXTREME HEAT AND PRESSURE APPLICATIONS

ANTI-SEIZE has incomparable lubricating qualities at temperatures below sub-zero and up to 750 F. It is so versatile no maintenance man or industrial plant should be without it.

Molylube ANTI-SEIZE is a staple, non-melting, multi-purpose lubricant with a phenomenal capacity to prevent seizing and galling at bearing pressures well over 100,000 psi.

AMONG HUNDREDS OF APPLICATIONS, MOLY-LUBE ANTI-SEIZE IS OUTSTANDING AS A:

- RUNNING-IN LUBRICANT
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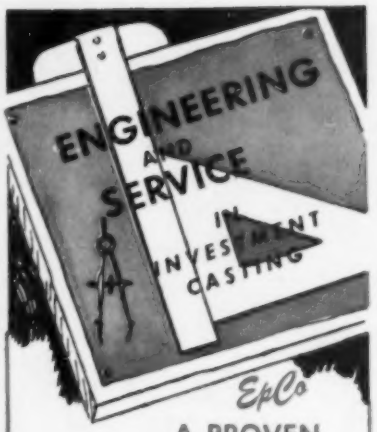

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FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

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Special Feature —Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

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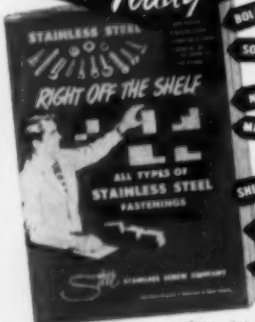

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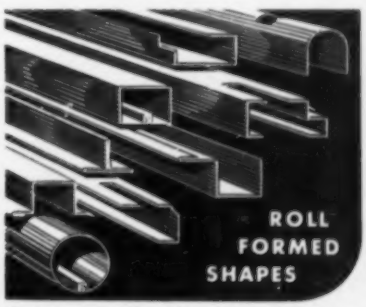

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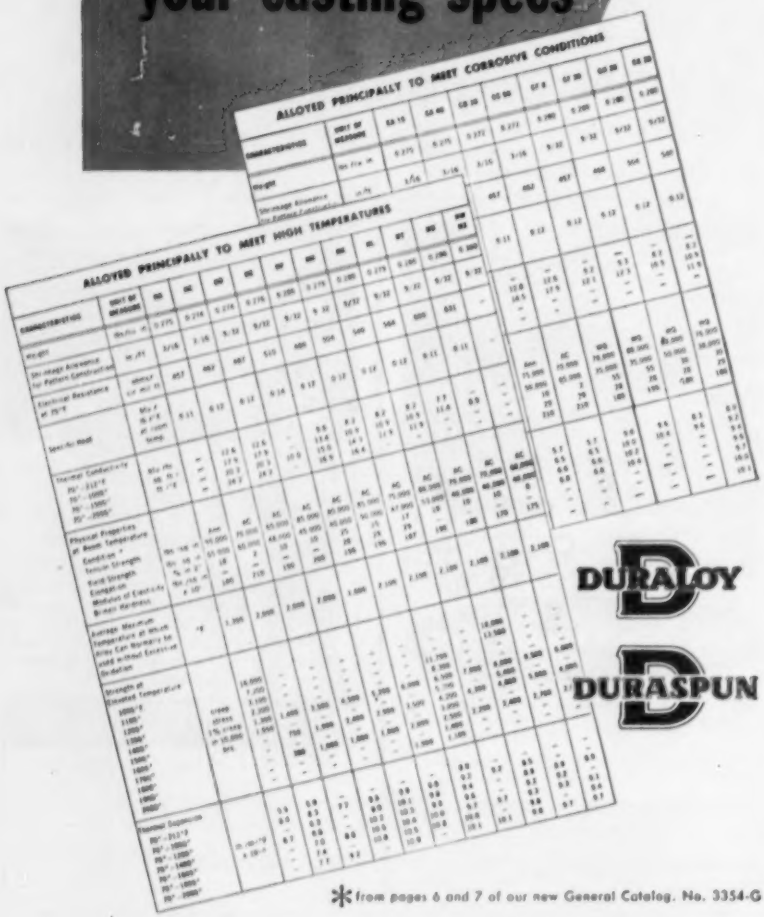

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Cracking in Carburized Parts

Digest of "Causes of Cracking in Carburized Parts and Measures for Preventing Them", by E. I. Malinkina, *Metallovedenie i Obrabotka Metallov*, 1955, No. 4, p. 39-47; No. 5, p. 24-28.

THE CAUSE of cracking in carburized parts is internal stress; therefore it is necessary to consider the magnitude of the stresses which can develop from various sources. For this purpose, the author has found it convenient to treat internal and surface cracks separately.

Internal cracks do not occur on uniform cylindrical or flat surfaces. This practical observation is in agreement with measured stresses in quenched carburized cylinders, for although internal tensile stresses were found, they were less than 15,000 psi. in magnitude. Thus, internal cracks can occur only at irregular sections where there are stress concentrations. Usually when cracking occurs the carburized layer is at least 0.060 in. thick and the core has a coarse acicular structure with a hardness of C-43 or higher. Internal cracks will continue into the core if the core hardness is greater than C-45. Two effective measures for preventing internal cracks are the use of fillets to decrease the sharpness of changes in section and immediate tempering after quenching to reduce the internal stresses.

The author believes that surface cracking is not as well understood as internal cracking, and most of his two papers is devoted to a new approach to the problem of surface cracking. The usual isothermal decomposition diagrams are not suitable for predicting the course of austenite decomposition in a carburized part because of the variation in carbon content from the surface to the core. Therefore, a new kind of diagram was plotted using data obtained from specimens carburized to a depth of 0.060 in. Thin wafers cut from the carburized stock were austenitized at 1630° F. and then allowed to transform isothermally at various temperatures from 1270 to 840° F. The data obtained in this manner were plotted for carbon content as a function of the time to pro-

Tool Steel Topics

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TOOL	HARDNESS ROCKWELL C
High-speed steel, metal-cutting tools, single point	65
High-speed steel, metal-cutting tools, multiple point	63
Blanking dies	60
Forming dies	60
Drawing dies, hardened all over	60
Drawing dies, bore-hardened only	66
Gages	60
Shock-resisting tools (punches, etc.)	58
Hot-work tools	40/50
Cold shear blades	60
Hot shear blades	48
Tools subjected to max tensile loads (cylinders, containers, etc.)	53
Tools subjected to max compressive loads (plungers, punches, etc.)	60/65

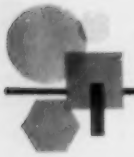
These hardness figures should be used as a guide only, because for individual jobs the required hardness may be slightly higher or lower, depending upon circumstances.

Tool Steel Color Film An Award Winner

"Teamwork," Bethlehem's 16-mm color film on tool steel, received an award for excellence in the sales promotion field at the recent Columbus Film Festival, held at Columbus, Ohio. The film, being received enthusiastically in all parts of the country, shows the manufacture of Bethlehem tool steels, and explains the reasons behind their quality control and heat-treatment. Typical applications of various grades are included.

The picture runs for 30 minutes. It is available for showings to machinists, diemakers, heat-treaters, machine-tool manufacturers and distributors. Its subject matter makes it excellent for technical society meetings, and for showings to engineering-student groups.

If you would like to see "Teamwork," drop a line to Publications Department, Room 1001, Bethlehem Steel Company, Bethlehem, Pa. If possible, please select a showing date well in advance, to permit adequate time for scheduling and shipping.



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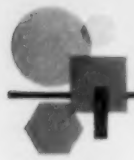

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Carburizing . . .

duce such decomposition products as ferrite or troostite at various transformation temperatures.

At 1270° F., austenite begins to decompose quickly (that is, in about 1 min.) at carbon contents above 1.0% and below 0.5%. At 0.6% carbon, on the other hand, decomposition does not begin for about 18 min. Because of these differences in rate of reaction at various positions in the carburized layer, it is clear that a nonuniform microstructure can be produced at certain cooling rates. Specifically, during air cooling of a carburized steel, it was found that troostite formed in the surface layer and martensite formed in a lower layer. This combination produces surface tensile stresses which can lead to surface cracking. This trouble was avoided by increasing or decreasing the rate of cooling.

The approach to the control of surface cracking presented here is a general one but it is clear that the dangerous rate of cooling will vary for different alloys.

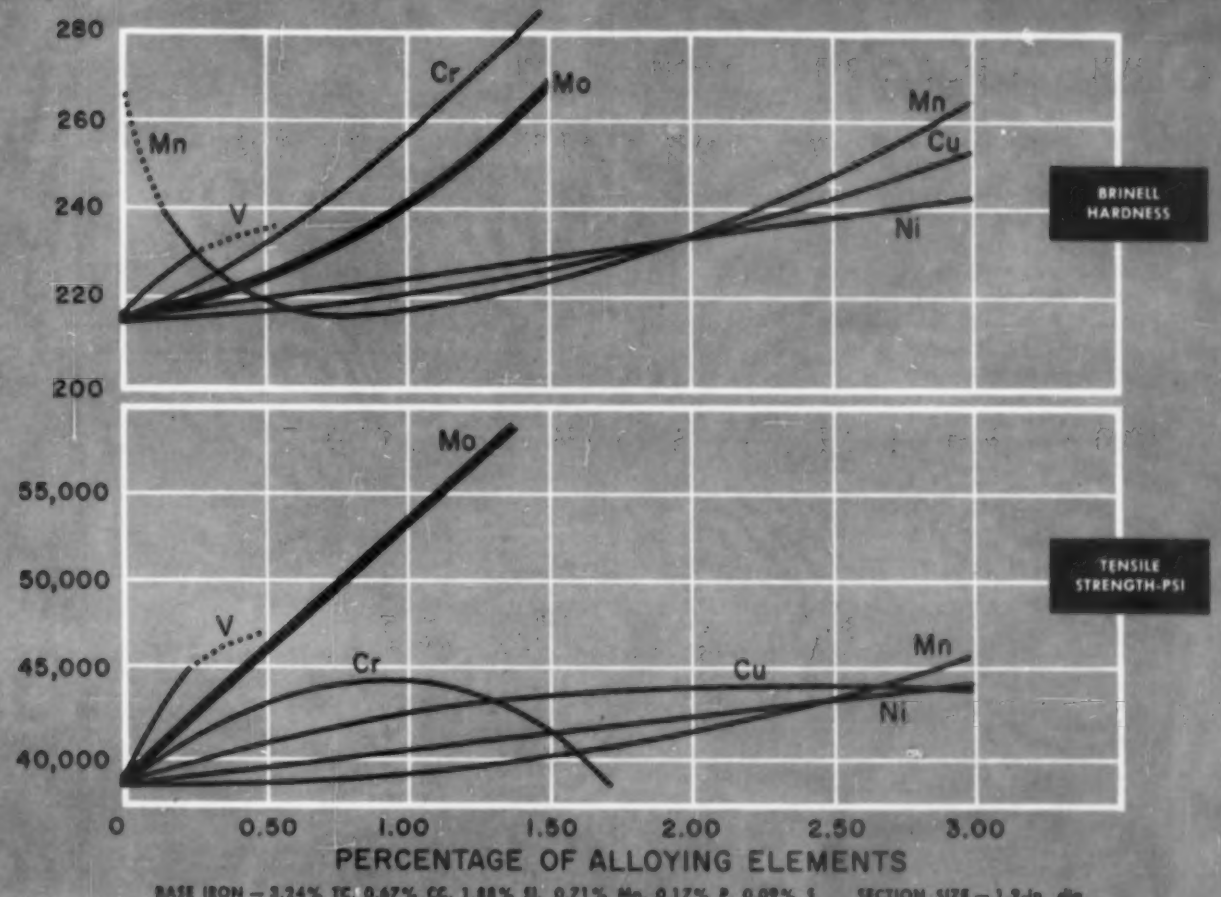
A. G. Guy

Dephosphorization With Moist Hydrogen

Digest of "Dephosphorization of Alloys by Hydrogen", by P. C. Ghosh and B. Chatterjee, *Journal* of the Iron & Steel Institute, Vol. 182, February 1956, p. 153 to 155.

The comparative dephosphorization of phosphor copper, ferrophosphorus and a high-phosphorus cast iron by wet and dry hydrogen and nitrogen was investigated from 930 to 1830° F. The materials studied contained 14, 26.6 and 1.1% phosphorus, respectively.

Experimental procedure consisted of placing 5-g. samples of the powdered alloys in boats in a quartz tube furnace and then passing the gases over the sample after the furnace had been adjusted to the desired temperature. Hydrogen is more effective in removing phosphorus from the alloys than nitrogen, and moisture in the gas enhances the rate of dephosphorization. A distinct smell of phosphine is perceptible in the exit gases only when dry hydro-



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Dephosphorization . . .

gen is used. Tests for phosphine were not performed when cast iron was used because hydrogen sulphide, formed in the interaction between hydrogen and sulphur in cast iron, would react with the reagents and change the color of the precipitate.

If it is assumed that nitrogen is an inert gas and that the observed loss of phosphorus when using dry nitrogen is due to volatilization, the minimum phosphorus vapor pressure over ferrophosphorus is about 10^{-4} atm. This value is very high compared with that calculated from thermodynamic data on phosphides. It is assumed that phosphorus forms a nitride (P_3N_5) and although it will be almost completely dissociated at 1830° F., its formation may be the reason for the high minimum phosphorus vapor pressure over ferrophosphorus noted in the present investigation. The ferrophosphorus used probably has the composition Fe_2P and X, X being an alloy of unknown composition which may have some effect, even if small, on the observed high minimum phosphorus vapor pressure.

It is obvious that wet hydrogen yields the greatest amount of dephosphorization. When the gases leaving the furnace are passed through various reagent solutions, phosphine is present with dry hydrogen while this poisonous gas is entirely absent when wet hydrogen was used. The phosphine is probably oxidized to the pentoxide in the presence of water as indicated by the presence of phosphoric acid in the effluent gases.

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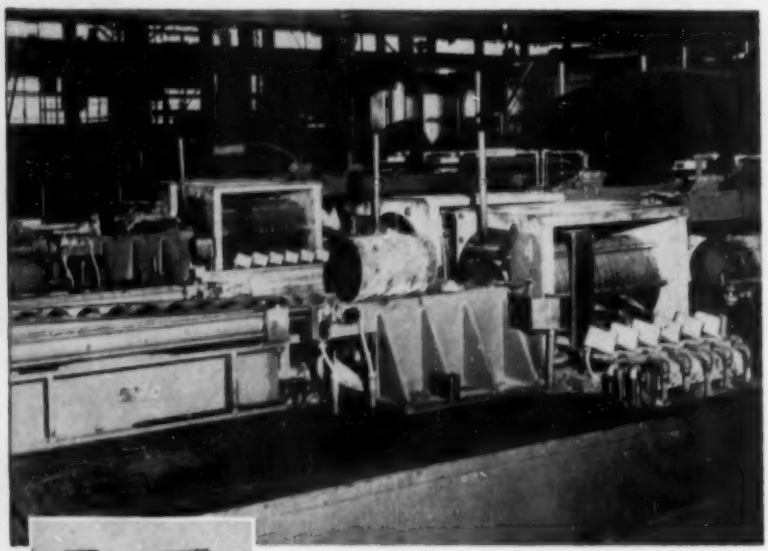

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Hardenability of Gray Iron

Digest of "Effect of Section Size on the Quenching Sensitivity of Grey Cast Iron", by A. D. Lamb, *Journal of Research and Development*, British Cast Iron Research Association, Vol. 6, April 1956, p. 184-194.

WHILE ALLOYS ADDITIONS are known to improve the hardenability of gray iron, little has been ascertained about the effect of section size. To develop such data, experiments have been carried out on 2.1 and 4-in. diameter bars of plain iron and two alloyed irons.

Three 300-lb. melts were made and from each of these, three small and three large bars were cast in green sand molds, all measuring 16 in. long plus a feeder head. Charges were made up from a single analysis of pig iron and in each of the three melts the composition was adjusted by the addition of ferrosilicon and ferromanganese. Nickel-molybdenum additions were made to the second melt and copper-molybdenum to the third.

Two 2.1-in. and two 4-in. diameter bars were taken from the set of six bars poured for each of the three melts. To eliminate the effect of variation in mechanical properties between the top and bottom of the bar, each was cut in half and the top of one and the bottom of the other used to prepare tensile specimens. The latter were of two sizes,

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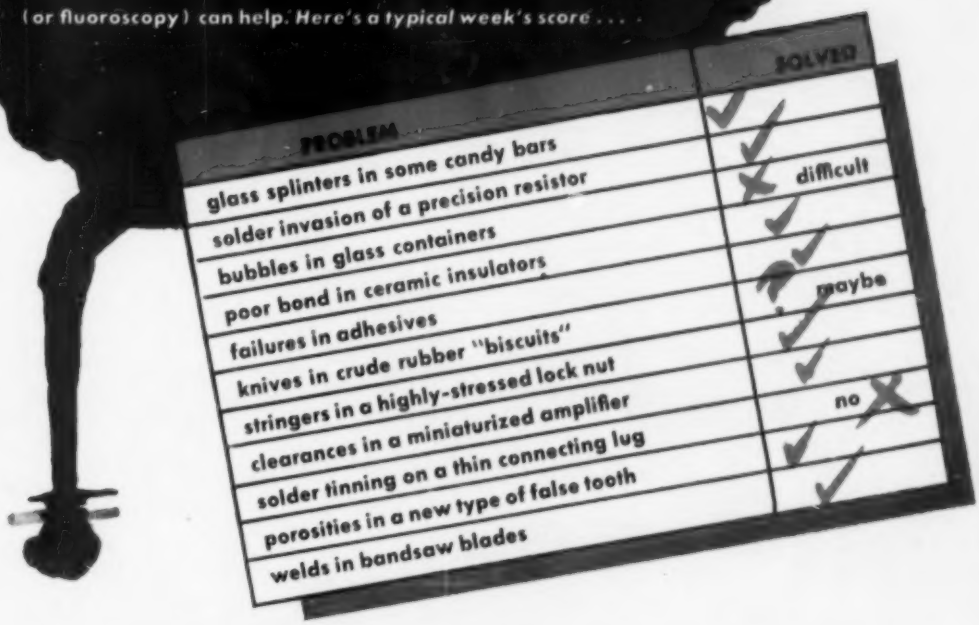
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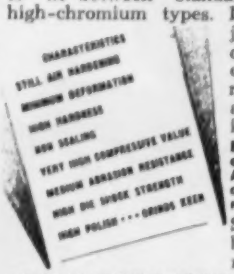

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Hardenability . . .

0.399 in. and 0.564 in. in diameter, cut from across the center line of the bars, five from the larger bars and two (center and edge) from the smaller bars.

Hardness measurements were taken on the shoulders of the tensile specimens after breaking. As might be expected, tensile strengths and hardnesses varied unimportantly between the top and bottom specimens but were somewhat higher on the outside area of the cast bar than toward the center. In general, the same was true of the as-cast alloyed samples.

Heat treatment of samples of the three irons followed this procedure: The bars were heated in a gas-fired furnace and soaked all night at 570° F., followed by 1¾ hr. at 1200° F. and then an increase in temperature to 1600° F. in 40 min. for a 30-min. soak. Castings were oil quenched in a large tank and allowed to cool in the oil. Flats were ground on the sides for hardness readings. Quenching was followed by tempering at 1020° F.

Typical hardness readings on the unalloyed 0.399-in. diameter bars as-quenched were Brinell 429 on top sections and 444 on bottom sections; after tempering, Brinell 297 on top sections and 295 on bottom pieces. On specimens from the 4-in. bars, similar averages were Brinell 352 on top and 363 on the bottom as-quenched; 282 top and 265 bottom after tempering. No significant conclusions could be drawn from these scattered readings.

On oil quenched and tempered bars of 0.798-in. diameter machined from the centers of the as-cast specimens, tensile tests showed a slightly higher value than those taken from near the edge, but this might be explained easily by the usual scatter experienced with several bars of identical composition and treatment. On the other hand, the section sensitivity of the smaller diameter bars might be slightly more pronounced, which would account for the increased tensile strength.

Averages of tensile strengths and hardnesses of the three melts ranged progressively upward from the unalloyed material to the copper-molybdenum analysis. Thus, the hardness of quenched and tempered

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Hardenability . . .

bars of Ni-Mo iron 2.1 in. in diameter was 337 to 347, and of the Cu-Mo bars in similar diameter, hardness was 347 to 352.

From the many "single" tensile tests conducted, no conclusive determinations can be drawn, particularly in view of the known scatter possibilities. Data from the experiments therefore can be regarded only as indicative of a trend and would not necessarily be reproduced in materials of these compositions coming from different foundries.

ARTHUR H. ALLEN

Mechanical Properties at Very Low Temperatures

Digest of "Strength and Ductility of Metals at Low and Extremely Low Temperatures", by G. V. Uzhik, *Isvestiya Akademii Nank SSSR*, No. 1, 1955, p. 57-66.

THE MECHANICAL PROPERTIES of metals may be determined at temperatures down to −320° F. with little experimental difficulty. However, some materials such as the austenitic steels and many nonferrous metals do not exhibit brittle fracture at such temperatures. It was the author's object, therefore, to develop a technique for measuring the mechanical properties of metals at temperatures down to that of liquid hydrogen, −422° F. The apparatus consisted of a Dewar flask arrangement, the inner tube of which was made of stainless steel which has a low thermal conductivity, and the outer tube was made of copper. The lower end of the flask is attached to a shackle which fits into the bottom chuck of a universal testing machine. The upper shackle, attached to the other end of the specimen, passes through the cover of the Dewar flask and is attached to the top chuck of the machine.

Stress-strain curves obtained at −422° F. on an austenitic steel, E 1/a IT (similar to A. I. S. I. Type 321), suggested an analogy between the plastic deformation of a single crystal and a poly-crystalline alloy. In liquid hydrogen, the first onset of plastic deformation was accompanied by a "zigzagging" of the deformation

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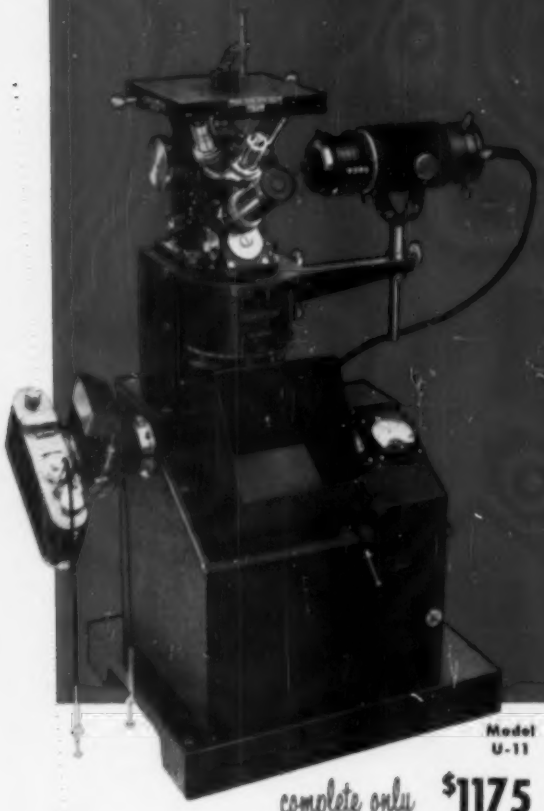

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Low Temperatures . . .

curve and by a clicking noise characteristic of the formation of twins. Above the yield point, slipping seems to be the predominant mode of deformation until the point of maximum load, beyond which twinning again takes place. The behavior is very similar to that of single-crystal specimens of cadmium which exhibit discontinuous stress-relief through the formation of twins and twinning after slip.

The yield point, in the author's opinion, is the most important property of a metal at low temperature. Local stress concentrations can be reduced by plastic flow with a resultant decrease in stress peaks. Hence, evaluation of the behavior of an alloy at low temperatures should be based on the relation between the change of shear strength and the decrease in temperature.

The results of the present investigation showed that the tendency of metals to increase their shear strength at low temperatures depended on the value of this property at normal temperature and the composition of the material. The lower the yield point at room temperature, the more this value changed when the temperature was lowered. For example, samples of Armco iron showed an increase in yield strength of 300% at −320° F. and 400% at −422° F., and stainless steel increased in yield strength by 130% at −320° F. and 140% at −422° F. A high-tensile steel increased in yield strength by only 10 to 20% at −320° F. Although the yield strength of the Armco iron was lower than that of stainless steel at ordinary temperature, it exceeded the yield strength of the stainless steel at lower temperatures. The author believes that this indicates the greater tendency of low-carbon steels to fracture in a brittle manner at low temperatures.

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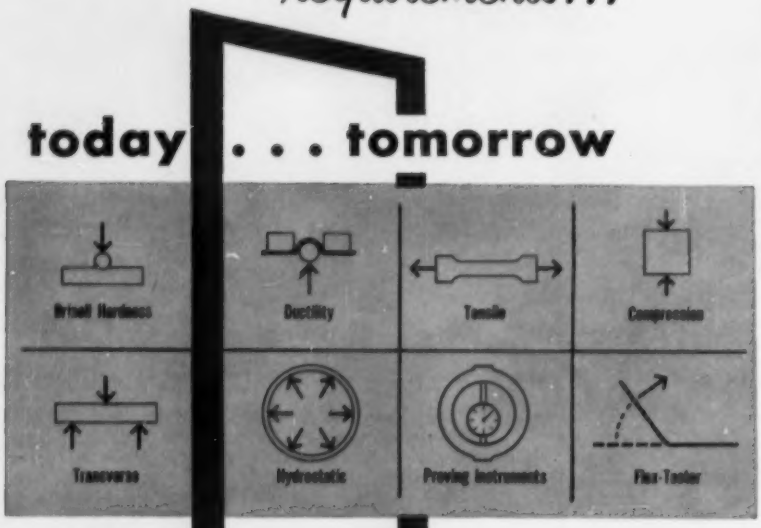

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Vertical Continuous Casting of Steel

Digest of "On The Development of Vertical Continuous Casting of Steel", by Karl G. Speith and Adolf Bungeroth, *Stahl und Eisen*, Vol. 76, April 19, 1956, p. 437-441.

EVERY PRODUCTION method is judged on the basis of technical merit as well as quality of its product and the production cost. This paper is concerned with vertical continuous casting installations where, on the basis of existing developments, it appears that the technical problems can be solved and the operation has definite possibilities of being economical.

Continuous casting from a small-capacity holding furnace enables the use of very extended pouring times at uniform rates of flow and virtually constant metal temperatures. When the pouring furnace is to take the steel from one or more melting furnaces, it can be operated on a continuous basis.

There are also some disadvantages to this method which can be tolerated with small melts but cannot be avoided with large ones. The double transfer from the melting fur-

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Continuous Casting . . .

nace to a transport ladle and then to the holding furnace results in a high heat loss. Consequently, it is necessary to superheat the steel in the melting furnace if a further reheating of the metal in the holding furnace is to be avoided. This may not be practical in some instances since the higher temperature will result in more wear of the furnace lining and lead to metallurgical variations in the melt.

The rate of casting can be increased by increasing the capacity of the molds or by pouring several ingots simultaneously.

In the method usually used in steel plants – that is, pouring the metal from the ladle directly into the mold to form a static chill casting – a definite ratio of pouring weight to pouring time may not be exceeded. Although the rate of casting is lower, similar ratios apply in continuous casting. However, in the latter instance larger ladles of molten steel are used.

One or two-unit continuous casting systems require more headroom than multi-unit installations but are relatively simple to arrange. They require a high rate of casting. At high pouring rates, ingot quality is reduced. In this type of installation, the risk of accidents is greater.

Multiple-unit continuous casting installations have a lower structural height, but require more extensive equipment. However, this method avoids excessively high pouring rates. Either the tilting ladle or bottom-pour ladle can be used for regulating the flow of steel into the molds. Continuous casting from bottom-pour ladles feeding into four bottom-pour distributors, as in the authors' plant at Huckingen in Germany, provides a simple, practical, safe system.

The experience gained in Huckingen with a four-unit bottom-pour continuous casting system has shown that it is possible to increase the number of units. However, for practical purposes it is best to use the minimum possible number of units.

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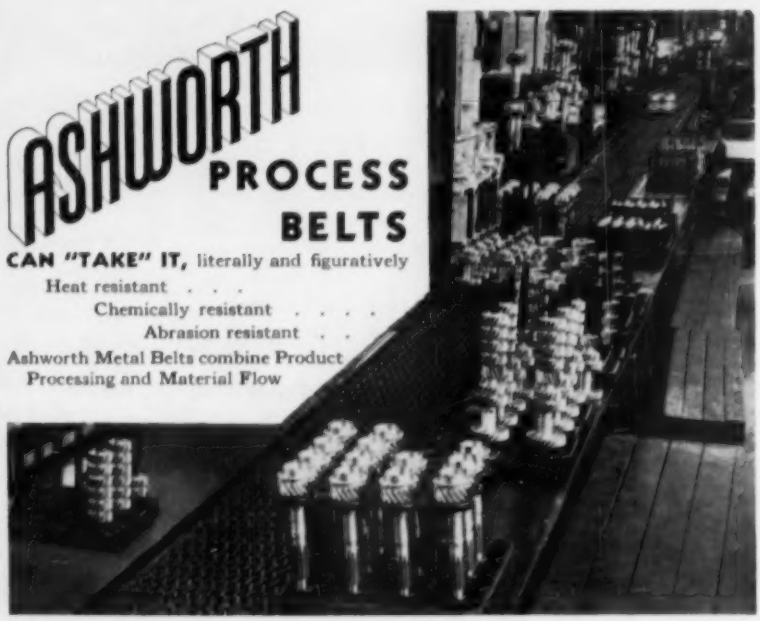

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Properties of Phosphor Bronze

Digest of "The Mechanical Properties of Wrought Phosphor Bronze Alloys", by G. R. Gohn, J. P. Guernnd and H. S. Freynik, A.S.T.M. Special Technical Publication No. 183, 1956.

THE ADDITION of tin increases the strength of phosphor bronze alloys, and a given amount of tin causes a greater increase in strength at lower concentrations than at higher concentrations. The increase in strength resulting from cold working is greater for high concentrations than for low. There is marked increase in tensile strength for tin additions as low as 0.5%. The proportional limit is also increased with increasing tin content, the greatest increase being observed with the increase from 2 to 3%. Increases in tin above 5% cause little increase in the proportional limit of the various rolled tempers. Alloys containing less than 2% tin show little increase in yield strength when cold rolled more than 50% and higher tin alloys show little improvement when cold rolled in excess of 37.4%. In most instances, the improvement in yield strength resulting from increasing the tin content beyond 5% is so small that the benefit is offset by the marked reduction in formability characteristic of high-tin alloys. The yield strength is so close to the tensile strength values that the alloys are unsuitable from a design standpoint.

For any given temper, an increase in tin content usually results in an increase in ductility. In the annealed, half-hard and hard tempers, the 8% tin alloy has substantially better elongation than does the 10% tin alloy. A study of the curves showing the relationship between ductility and tin content reveals the occurrence of a ductility peak at 8% tin. However, this good ductility should not be confused with good formability since experience has shown that the high-tin alloys have very poor formability.

The addition of tin to copper results in an increase in fatigue strength at all tempers. This increase is as much as 250% in the annealed tempers for alloys containing 5% tin or more. With tin contents of 0.5 to 3%, increasing amounts of cold work improve the fatigue strength. For tin additions of 3, 4 and 5%, cold rolling in excess of 37.4% has but little effect, while for tin additions of 8 and 10%, cold working in excess of 20.7% appears to have no beneficial effect. Optimum fatigue results for all tempers treated as a group appear to be obtained with the addition of 5% tin.

A decrease in the grain size in the ready-to-finish anneal results in an improvement in tensile strength, especially for the annealed tempers. The yield strength is little affected by a smaller ready-to-finish grain size except for an improvement evident in the higher tin alloys. Elongation values are higher for 0.035-mm. material with a tin content of 0.5% while the opposite is true for alloys with 3% tin or more. A fine grain size appears to improve the fatigue strength except that of ETP copper and the harder tempers of the 8 and 10% tin alloys. At high tin concentrations

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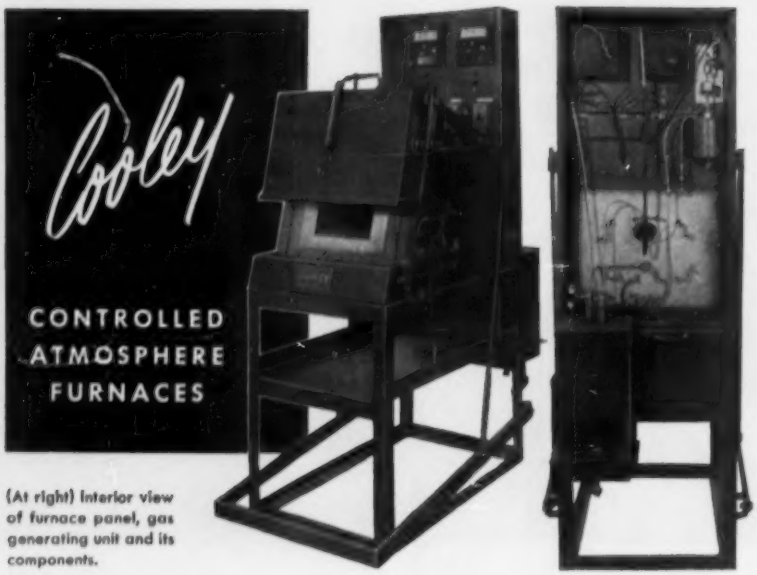

(At right) Interior view of furnace panel, gas generating unit and its components.

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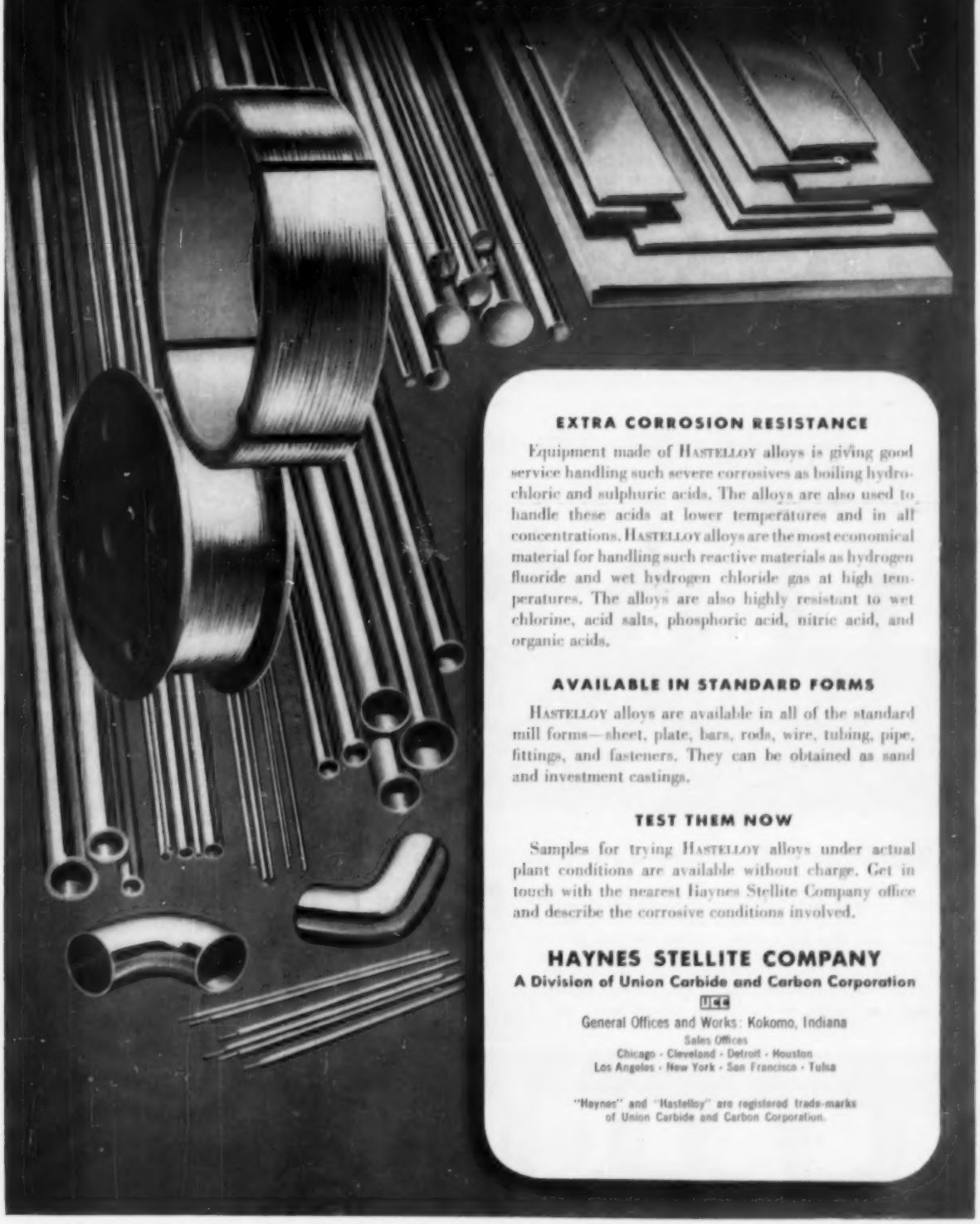

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Phosphor Bronze . . .

(5% or more) even the annealed temper has a fatigue strength close to those of the rolled tempers.

Where engineering properties such as fatigue strength and proportional limit are important, the optimum composition would appear to be 4 to 5% tin. Cold rolling in excess of 50% is not justified if the tin content is held within these limits. A fine grain size, 0.015 mm. or finer, is beneficial from a fatigue standpoint. A high phosphorus content permits a slight reduction in tin content without a significant loss in desirable engineering properties.

R. F. HARTMANN

Stress-Corrosion of Aluminum Alloys

Digest of "The Interactions of Static Stress and Corrosion With Aluminum Alloys", by F. A. Champion, *Metallurgia*, Vol. 53, February 1956, p. 63-68.

THE MOST DEPENDABLE method for determining the susceptibility of a material to stress-corrosion is to correlate the results from (*a*) specimens stressed under corrosive conditions, (*b*) specimens exposed to the same corrosive conditions but without stress, and (*c*) specimens subjected to stress in the absence of corrosive conditions. To avoid complications from the effects of creep, stress levels during experimental tests should be limited to 75% of the proof stress of the alloy in question. If the results of the foregoing tests show that the properties of the material deteriorated fastest under the simultaneous effects of stress and corrosion, it can then be concluded that the material in question is susceptible to stress-corrosion.

The identification of stress-corrosion as a cause of service failure is quite difficult. Such failures in aluminum alloys can only be positively identified if there is definite evidence of each of the following:

1. The material is known to be susceptible to stress-corrosion.

2. The main fracture and subsidiary cracks are intercrystalline. (Where there was breaking up or distortion of grains during previous work, it is extremely difficult to de-

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Stress-Corrosion . . .

termine whether cracks are intercrystalline.)

3. The material has been under stress and corrosion simultaneously. (The stress may be internal due to residual stress from fabrication or external due to service conditions.)

The relative susceptibility of different alloys to stress-corrosion often depends upon the corrosive medium involved. For example, the stress-corrosion of a 7% Mg alloy in a susceptible condition increases with increasing sodium chloride contents up to 9%. In very acid solutions, however, general attack is more likely to occur than stress-corrosion. On the other hand, moderate acidities such as those in mixtures of marine and industrial atmospheres are ideal for stress-corrosion. Humidity is also an important contributor to stress-corrosion with maximum effects occurring at around 80% relative humidity in salt spray tests.

In laboratory studies of stress-corrosion, due consideration should be given to whether the specimens are loaded under constant strain or constant stress. The former condition is representative of the internal stresses produced during production and fabrication while the latter is more representative of service conditions. Most of the failures from stress-corrosion have been found to arise from high internal stresses that occur during fabrication.

Failure of aluminum alloys by stress-corrosion is rarer in service than in laboratory tests. To reduce failures due to stress-corrosion, every effort should be made to avoid internal stresses which occur during fabrication and assembly. A very effective protection against stress-corrosion based on service experience is to clad Al-Cu-Mg alloys and Al-Cu-Mg-Si alloys with high-purity aluminum.

In conclusion, the author points out that aluminum alloys do not usually fail from stress-corrosion even though they are somewhat susceptible to intercrystalline corrosion. Extensive alloying and heat treatment tend to increase the susceptibility of aluminum alloys to stress-corrosion. Cladding, spray coating or painting after anodizing offer the best protection.

R. C. WILLIAMS

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Gas Turbines for Autos

Digest of "Turbines for Mobility", by John H. Bouin and Robert A. Harmon, *The Frontier*, Armour Research Foundadation, Winter 1955, p. 12.

Gas turbines rated at 100 to 500 shaft horsepower have been installed experimentally in standard and special automobile chassis, trucks, busses and military vehicles. They have the advantage of developing more torque at all speeds than the reciprocating gas engine – for example, at 40% of rated top speed the turbine develops 60% of rated horsepower and 150% of rated torque, whereas the corresponding figures for a reciprocating engine are 40% and 100%. The advantage is even greater at lower speeds, the turbine having maximum torque at zero speed. The turbine requires about one-third the space; it needs no radiator or cooling system, but to lower the fuel consumption an interchanger for transferring heat from exhaust to incoming air may be as bulky and heavy. Engine weights are somewhat below the weight of present-day engines on mass-produced automobiles and about 30% that of a four-stroke diesel. In the heaviest truck this may save a ton of dead load. Its oil consumption is small, but its high speed (up to 35,000 rpm.) requires top-notch bearings, balancing, and speed reduction gearing. While the gas turbine can operate on inferior fuels, its consumption is very high – about 0.85 lb. of fuel per brake hp-hr. at maximum rating and double that at 30 to 50% of full load (which is the ordinary demand on a passenger car engine). This can be lowered by increasing the temperature of operations, but this is already so high (about 1600° F.) as to require expensive alloying metals of quite limited supply, or a bulky and expensive regenerator (heat interchanger). Other disadvantages which will have to be surmounted are noise (which can be dampened more easily than noise from diesels) and high exhaust temperatures (which will probably be reduced by the heat interchangers mentioned earlier).

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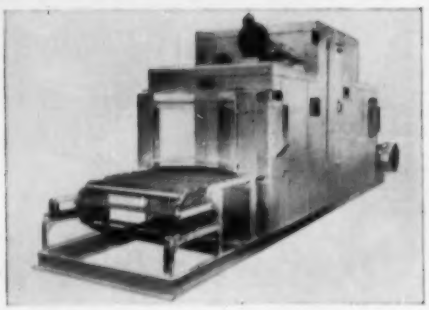

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Exclusive features of Young Brothers Ovens lead to savings in production time, prevention of loss of material and product improvement. Experienced engineers are available for consultation without obligation. Write for Bulletin 14-T.

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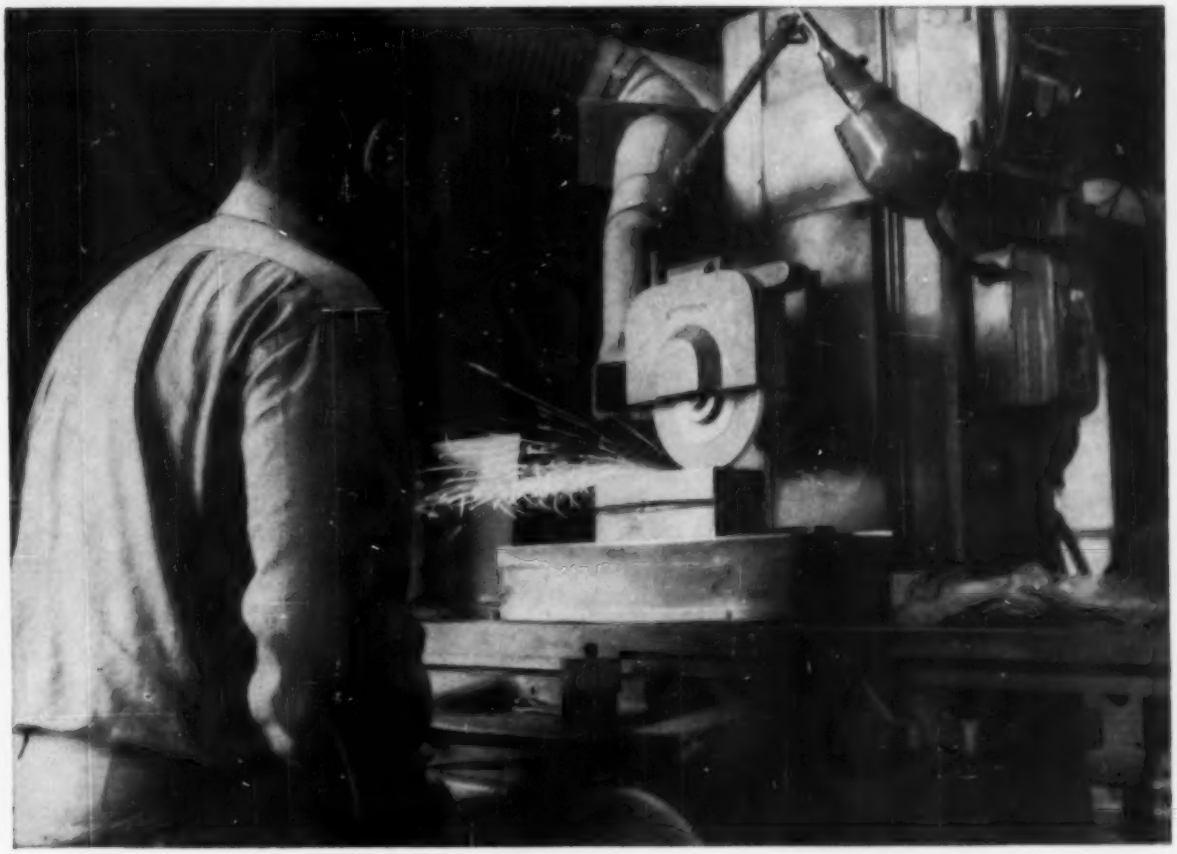
Production Control of Acid Bessemers

Digest of "Control in the Acid Bessemer Process", by P. J. Leroy, J. G. Galey and F. B. Cawley, *Journal* of the Iron and Steel Institute, Vol. 183, June 1956, p. 208-224.

This paper describes a detailed study of blowing conditions in a 25-ton acid converter using instruments developed by the Institut de Recherches de la Siderurgie (IRSID) in France. Three instruments were used for the control measurements, a volume "debitgraphe" which metered the air flow during the blow, an opacimeter which determined the end point of the blow after the carbon flame drop, and a flame pyrometer which recorded the flame temperature during the blow.

Initial tests indicated that large amounts of excess air were being blown. A calculation showed that the quantity of air necessary was 10,400 cu.ft. but with heats weighing between 19 and 25 tons, the air consumption actually varied from 13,500 to 20,900 cu.ft. per gross ton, indicating that a large amount of oxygen was escaping through the bath. The largest air consumption was observed in the smallest blow. The bath depth was given as 13 in. on old linings and 21 in. on a new lining for a 24-ton charge. The results also showed a direct correlation between silicon content of the hot metal and total air consumed.



"5 years ago Cities Service solved all our lubrication problems and we've never had another!"

A report from Banner Spring & 4 Slide Co., Van Dyke, Michigan

These Were The Problems 5 Years Ago: Banner Spring & 4 Slide Company, maker of small parts for the automobile, electrical and refrigeration industries, was having trouble. Ways, bearings, and drive shafts on 4 Slide machines were getting insufficient film strength from lubricants and constantly burning out. Likewise, compressors were also running hot, and there was complete puzzlement over what type of lubricant to use for Banner's high-speed sewing machines.

Banner decided to call in a Cities Service Lubrication Engineer. A thorough survey followed, with the man from Cities Service carefully examining each machine and its particular operating conditions.

This completed, he made his recommendations — Trojan H-2 Multi Purpose Grease for the 4 Slide machines, Pacemaker No. 1 Oil for the compressors, and Pacemaker 00 Oil for the high-speed sewing machines.

Banner followed these recommendations to the letter. Result: Not one lubrication problem in the past five years — despite the fact that machinery runs 24 hours a day!

If you're faced with a lubrication problem — or if you're just not sure if your present lubricant is best for the job — talk with the man from Cities Service. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

SOME BANNER PRODUCTS: The firm makes all kinds of round wire forms, wire springs, metal clips and flat springs. Use for such products ranges from auto fender support rods to "burlap listings"—the wire frames sewn into burlap which back up automobile upholstery.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

Acid Bessemers . . .

This varied from 14,000 cu.ft. for 1.78% Si to about 18,000 cu.ft. for 2.30% Si. The French basic converters used bath depths of 30 in. (twice that at Workington) and air consumption was about 13,000 cu.ft., a figure nearer the theoretical value.

The permeability of the converter is a measure of the ease with which air may be blown through it and is expressed as the blowing rate for a given blast pressure. The debitgraphe recordings showed a striking variation in permeability during various stages of the blow. The blow usually started with a blowing rate of 26,500 cu.ft. per min. at 20 psi., and then the pressure would gradually rise and the blowing rate fall, probably because of blocking of the tuyeres. After 7 to 8 min. blowing (1 to 2 min. before the start of the decarburizing stage), pressure would generally go through a peak corresponding to a minimum blowing rate. This maximum pressure was fairly constant for all tests at around 26 psi. On the other hand, the minimum blowing rate was rather variable, ranging from 18,500 to 25,000 cu.ft. per min.

Using the opacimeter, graphs were plotted for 25 blows to measure the relative cloudiness of the flame during the blows. The opacity increases rapidly from the start of the blow and passes through a peak during oxidation of the silicon. This peak corresponds to the emission of reddish fumes during the desiliconizing stage. Following this, the opacity decreases and passes through a minimum a short time after the start of the decarburizing stage. After this, it increases again and remains more or less unchanged until near the end of that stage. The sudden reappearance of red fumes causes a marked increase in opacity and the curve rises rapidly until the heat is turned down. There is fair agreement between the carbon content and the appearance of the kink in the curve, at which point the carbon content is 0.035 to 0.050%. Thus a means is provided of determining the point at which the heat should be turned down with an assured maximum carbon content of 0.05%.

The flame temperature gives an indirect measure of thermal changes in the bath, and in the course of the study, it was possible to establish an approximate rule for calculating the additions required for the control of final temperature based on a flame temperature reading made about 3 min. after decarburization began. The beginning of decarburization was determined from the appearance of the flame, which becomes brighter at this point, or from the temperature chart, which shows a sharp increase.

It is impossible to assess the extent to which steel quality and regularity of production by the acid bessemer process might be improved by the routine use of the instruments described in this paper, but preliminary tests have provided new information on the factors affecting air consumption per ton of iron, notably, the influence of bath depth, blowing rate and silicon content of the iron. They have also indicated how blocking of the tuyeres can be detected from permeability measurements, how opacity measurements can be used to give an end-point signal and finally, they have indicated the possibilities of simplifying and bringing refinement to the estimation of temperature at a sufficiently early stage in blowing to permit proper assessment of the scrap or ferrosilicon needed so that the blow will finish within the desired temperature range.

E. C. WRIGHT

Never Confuse the No. 8 MARVEL with an ordinary Band Saw

...only the MARVEL is Universal

Only on a No. 8 MARVEL can the saw column be instantly indexed and locked at any angle from 45° right to 45° left, and the saw then fed thru the work at the desired angle — without moving the work.
Only on a MARVEL No. 8 does the blade remain at a right angle throughout its full 18" feed traverse. Work always remains stationary.
Only a No. 8 MARVEL can do all of these things: Snip-off a ½" rod or cut-off an 18" x 18" cross section.
Rough to Size and Shape
Miter
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cut off and shape Structural Beams
Only a No. 8 MARVEL has the large T-slotted work table, with removable quick action vise, that permits accurate set-ups of work of unrestricted sizes and shapes, special fixtures, Etc.

"Rough Machine" to size and shape with minimun chip waste

The No. 8 MARVEL is the "busiest tool in the shop" wherever installed because it is a *universal* tool—has both the capacity and the versatility to handle not only standard sawing jobs but innumerable "trick" and convenience jobs as well. More than a metal saw, the No. 8 MARVEL is a fine machine tool with machine tool features like: Both power and hand feeds; Depth Stops; Automatic Blade Tension; Built-in Coolant Pump; Three operating speeds (or six with 2-speed motor). Moisture-proof electrical controls that conform to both "J.I.C." and "MACHINE TOOL" electrical standards; Dirt-proof ball bearings, etc.

If you cut, machine or fabricate metal, this is a sawing machine you should know about. Write for catalog.

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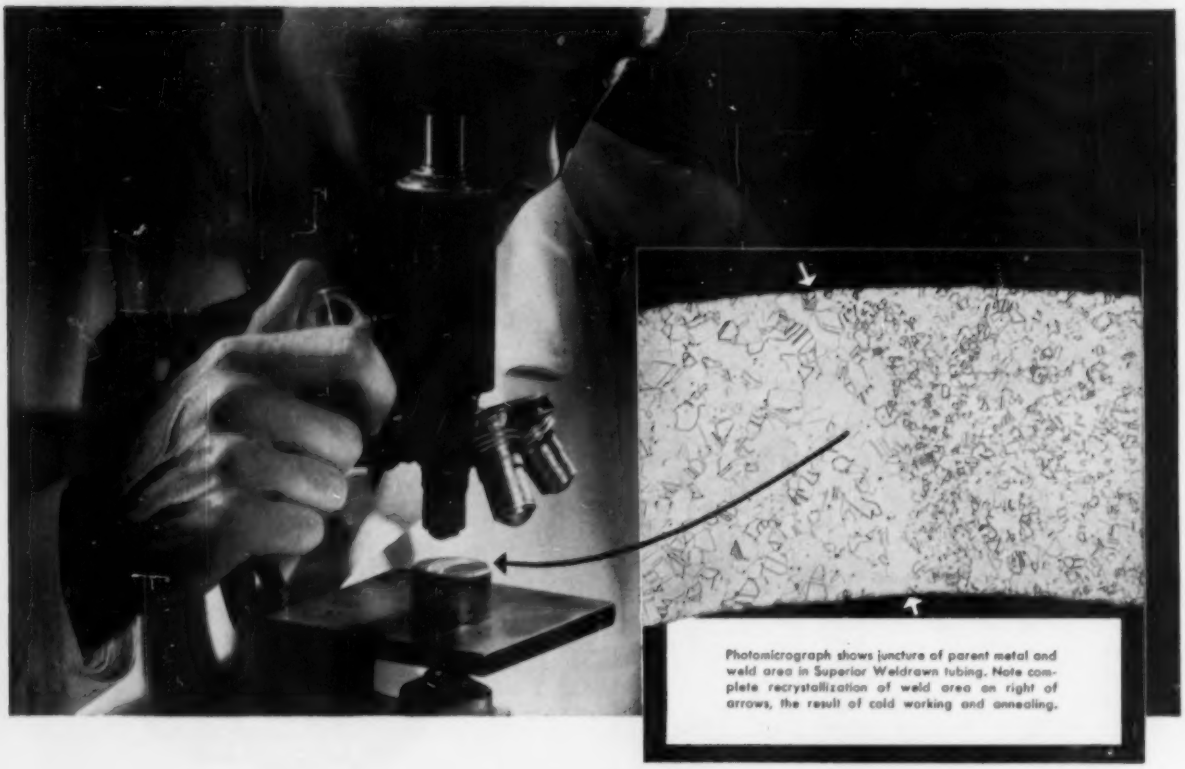
Weldrawn® Tubing *by* Superior



Photomicrograph shows juncture of parent metal and weld area in Superior Weldrawn tubing. Note complete recrystallization of weld area on right of arrows, the result of cold working and annealing.

So perfect the bead actually vanishes!

Here's how to cut tubing costs up to 50%

Specify Superior Weldrawn. You get quality approaching that of seamless, at savings as high as 50%! Unlike other welded tubing, Weldrawn is offered in *any* of the intermediate sizes—made possible because of the redrawing after welding.

"Weldrawn" Means—

This is a tubing far superior to ordinary welded tubing for many applications requiring forming, machining and corrosion resistance. After welding, it undergoes alternate cold drawing and annealing.

The weld area recrystallizes (see photo above), acquiring mechanical properties equivalent to those of the parent metal. The bead actually vanishes!

Costs Are Low

Weldrawn tubing is produced in 18 different analyses, in a wide variety of sizes. Cost savings are 10 to 20%. In certain materials you save up to 50%!

Quality Is High

In Weldrawn you get tubing with highly uniform mechanical properties throughout, and clean, smooth, bright ID and OD surfaces. Because no filler or flux is used during welding, the corrosion resistance of the weld area is equal to that of the parent metal. And by repeated redrawing and annealing after welding, any possible faults or defects in the weld are eliminated.

Specify Superior

In addition to Weldrawn tubing, we also offer a wide variety of analyses and sizes in Seamless grade. So for the finest in small tubing, always specify Superior.

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The big name in small tubing

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All analyses available in .010 in. to ⅝ in. OD—certain analyses in light walls up to 2¼ in. OD

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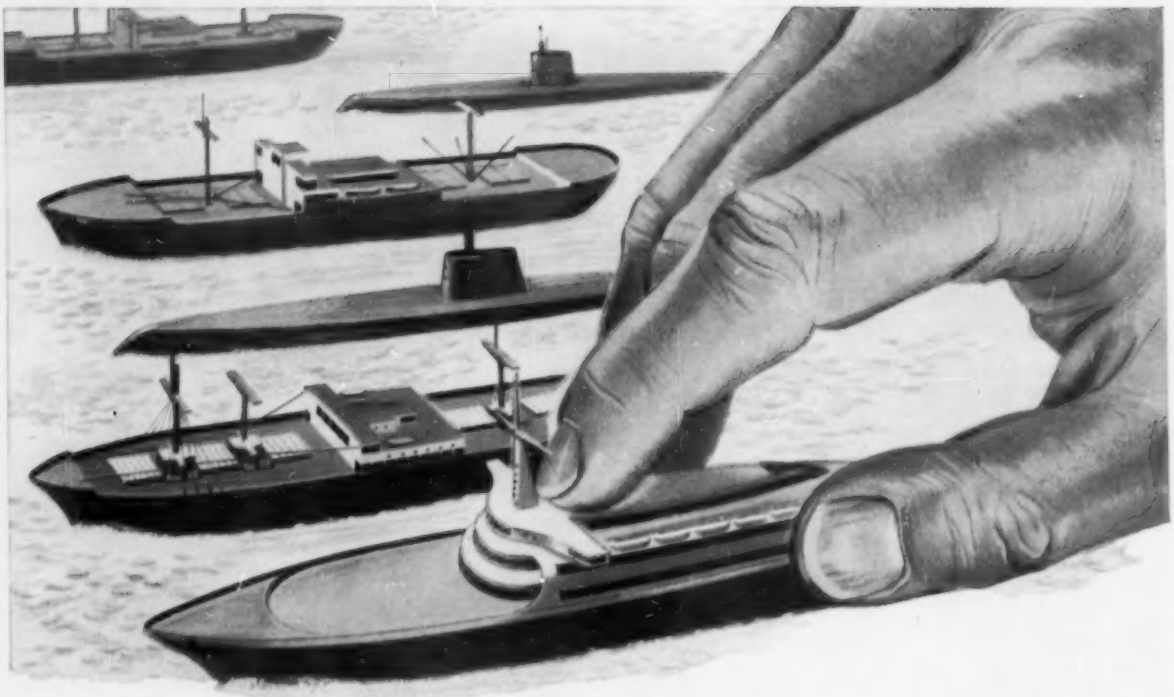

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At the country's largest design-engineering center for nuclear power reactors, Bettis Plant in Pittsburgh, operated for the Atomic Energy Commission by Westinghouse, the application of nuclear power has progressed rapidly. However, the nuclear power plants already in operation today represent only the beginning of a new technological era. *Major advances in many areas are necessary.*

These include: the development of fuel alloys; the development of clad alloys; fuel element development; and technical control of fuel elements and fuel and clad alloys. At Bettis you will have a choice of working in either Basic or Applied Metallurgy. You may prefer to conduct basic research in areas like these: 1) Solid phase transformation, 2) Corrosion kinetics and mechanisms, 3) Effect of irradiation on metals, 4) Internal friction studies, 5) Study of equilibrium diagrams.

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Write for descriptive brochure on opportunities in your field. Be sure to specify your interests. Address Mr. A. M. Johnston, Westinghouse Bettis Plant, Dept. A98, P.O. Box 1468, Pittsburgh 30, Pa.

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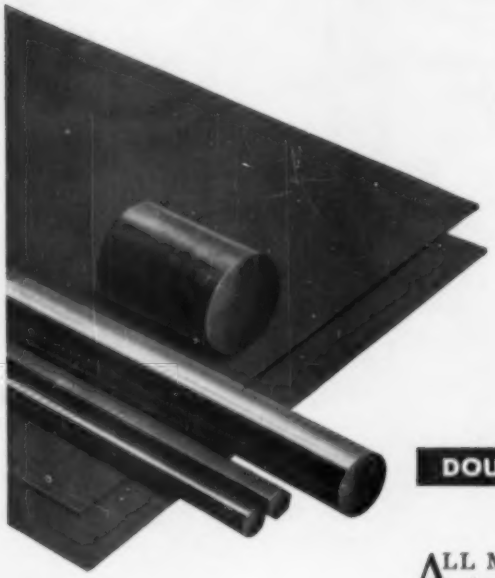
TITANIUM



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MST 4Al-4Mn—A heat-treatable alpha-beta bar and forging alloy which is primarily used in the annealed condition. It has good elevated temperature properties. Eutectoid decomposition is so sluggish that it never occurs in commercial applications.

MST 8 Mn—An alpha-beta sheet alloy used primarily in the annealed condition. It has good formability and may be used at moderately elevated temperatures in the annealed condition. Eutectoid decomposition is so sluggish that it does not occur in commercial applications.

TYPICAL MECHANICAL PROPERTIES

	Form	Ultimate Tensile Strength, psi	Yield Strength, psi	Elongation % in 2"
MST Grade III (Unalloyed)	Sheet, Bar	70,000	50,000	25
(3 different strength levels)	Sheet, Bar	85,000	65,000	23
	Sheet, Bar	100,000	80,000	20
MST 6Al-4V (1)*	Bar	140,000	130,000	13
(2)	Bar	170,000	150,000	12
(3)	Bar	135,000	125,000	12
(3)	Sheet	130,000	120,000	12
MST 3Al-5Cr	Bar	155,000	145,000	13
MST 4Al-4Mn	Bar	145,000	135,000	14
MST 8 Mn	Sheet	135,000	120,000	15

* (1) 1500—½—AC (3) 1525—1—FC to 1100-AC
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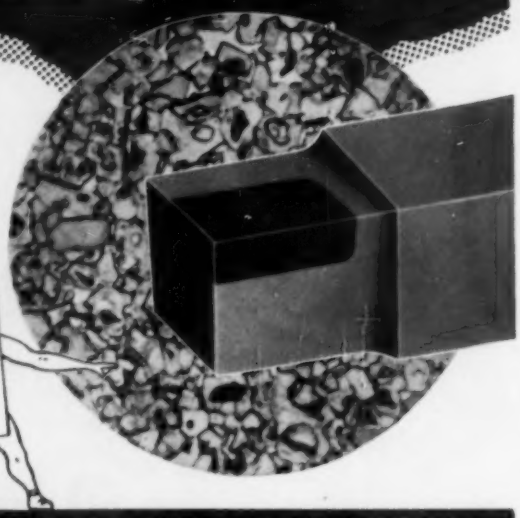

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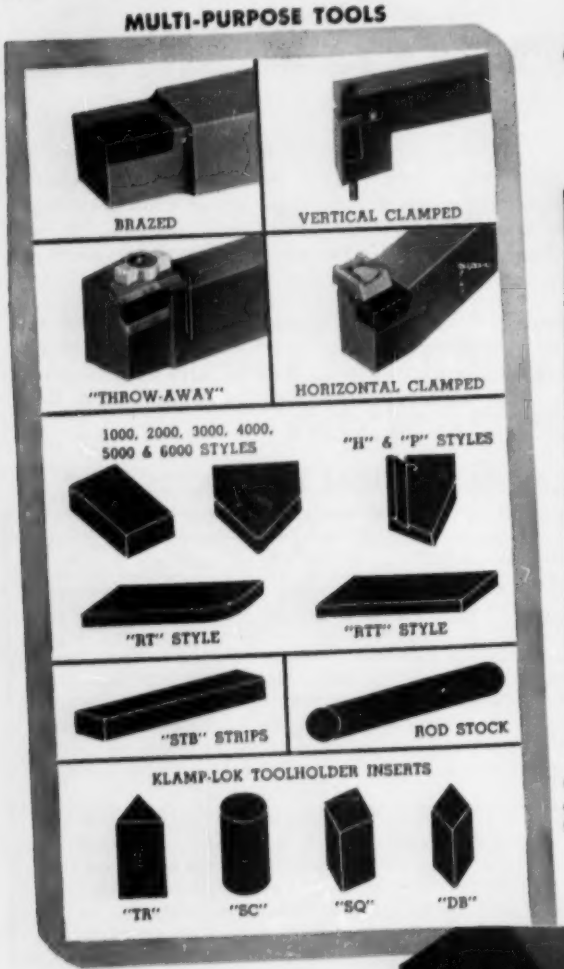

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Part.....C-1141 steel forging 1-1/2" dia. x 14" long.
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Machine.....New Britain Chucking Lathe.
Tool.....Talide triangular insert #TB-12123, Grade S-88 (Industry Code C-5), mounted in Klamp-Lok Toolholder.
Depth of Cut.....1/8" to 3/32" R.P.M.....1540
S.F.P.M.....580 Lubrication.....None
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Results.....31 shafts machined per edge per grind. Best competitive premium grade produced only 16 before fracturing. Exceptional toughness of Talide grade evidenced by only slight mushrooming of edge—no fracturing.

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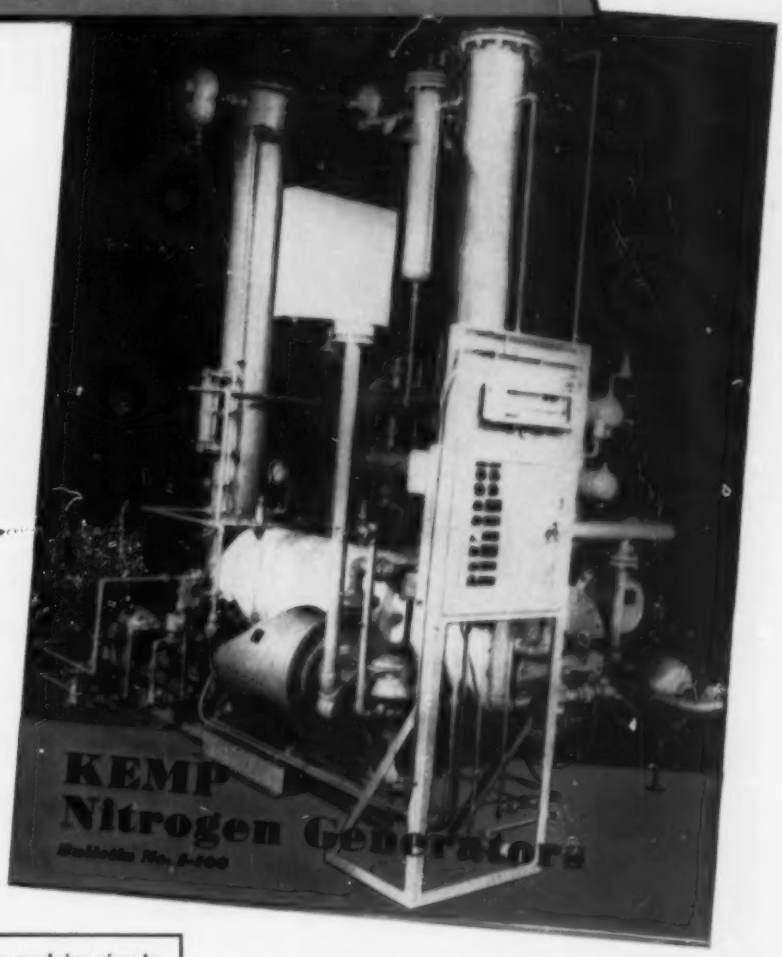

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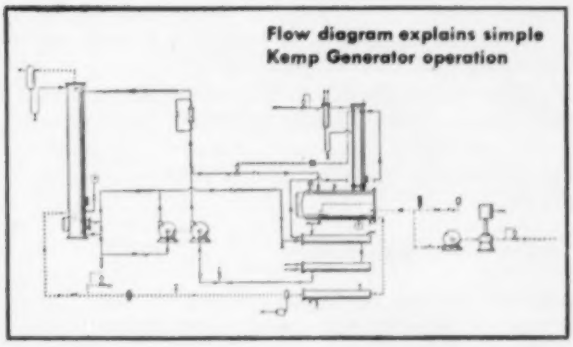

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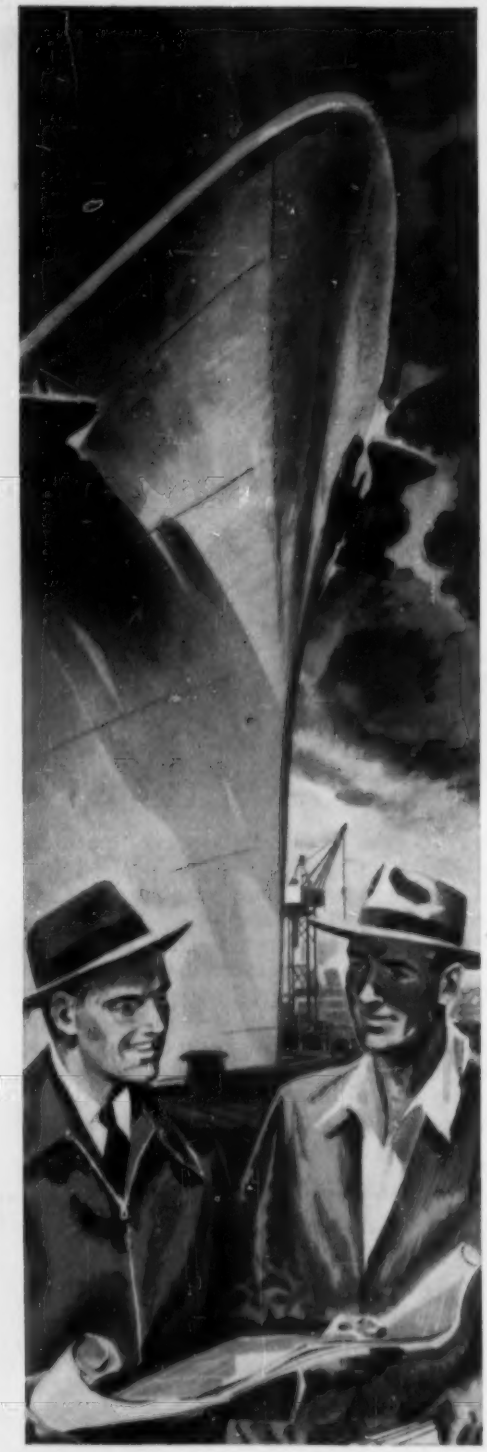

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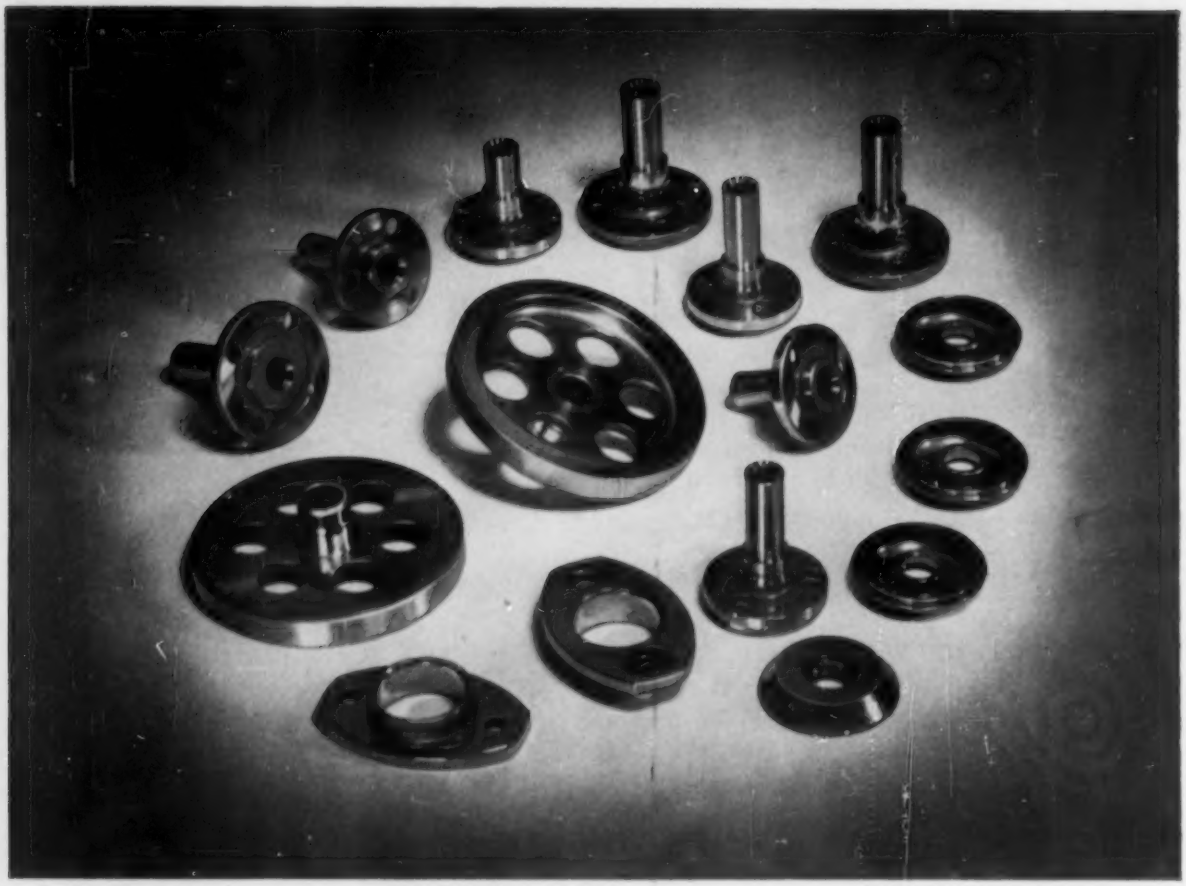

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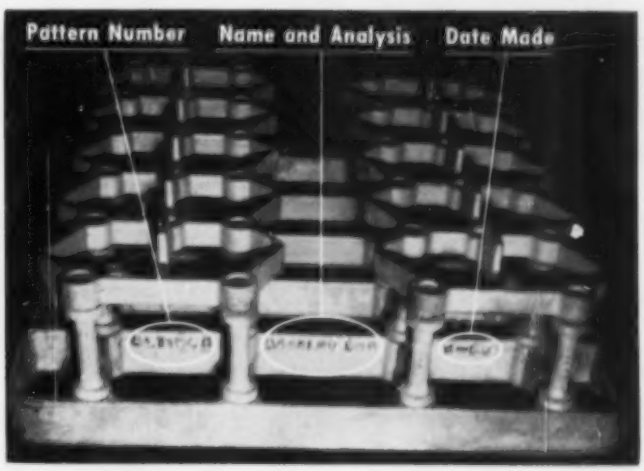

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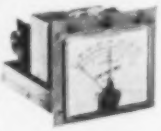

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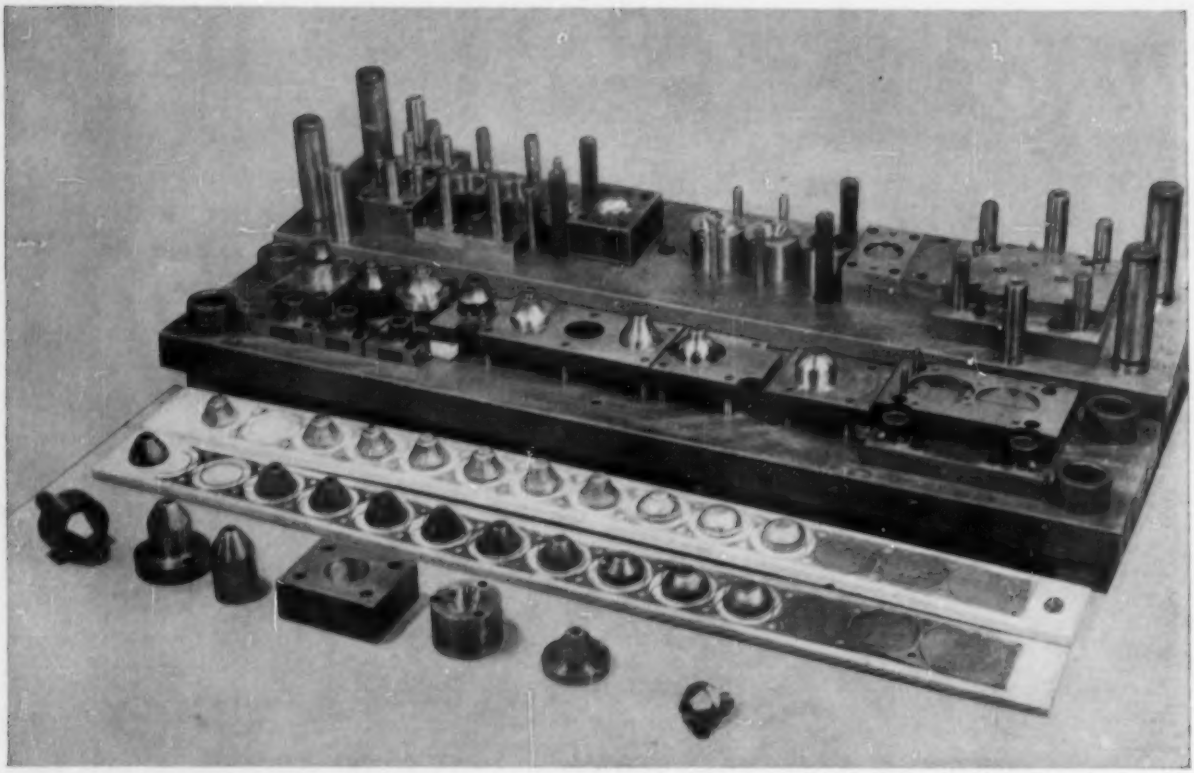

Unique punch and die of the Guarantee Specialty Mfg. Co., Cleveland, Ohio, with change tools and part progress strip in the foreground.

Revolutionary Progressive Die Produced From UHB-46

Advanced Ideas in Die-Making Take Shape with UDDEHOLM Tool Steel

Shown above is one of the most remarkable dies seen in recent years. Exhibited at the last A.S.T.E. Show, it created a bee hive of interest – provoking such typical comments as "twenty years ahead of times." Reaction to its appearance promises some radical changes in the future approach to practical die design. This is not surprising since it was designed by Ernest J. Urbas of the Guarantee Specialty Mfg. Co., of Cleveland, an organization with extremely advanced ideas in this field. Even less surprising was Guarantee's choice of tool steel for these revolutionary designs – Uddeholm Tool Steel, exclusively. For at Uddeholm they found a dependable source of the overall high quality needed for such versatile and extended die performance.

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March 25 through 29, 1957

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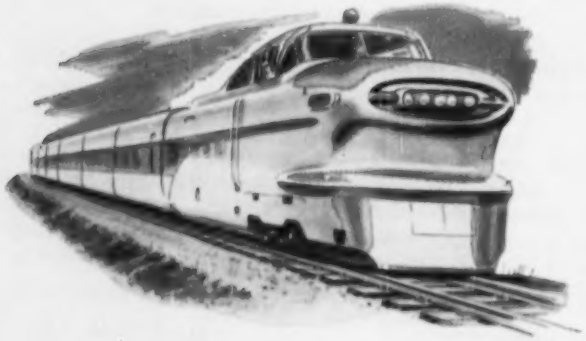

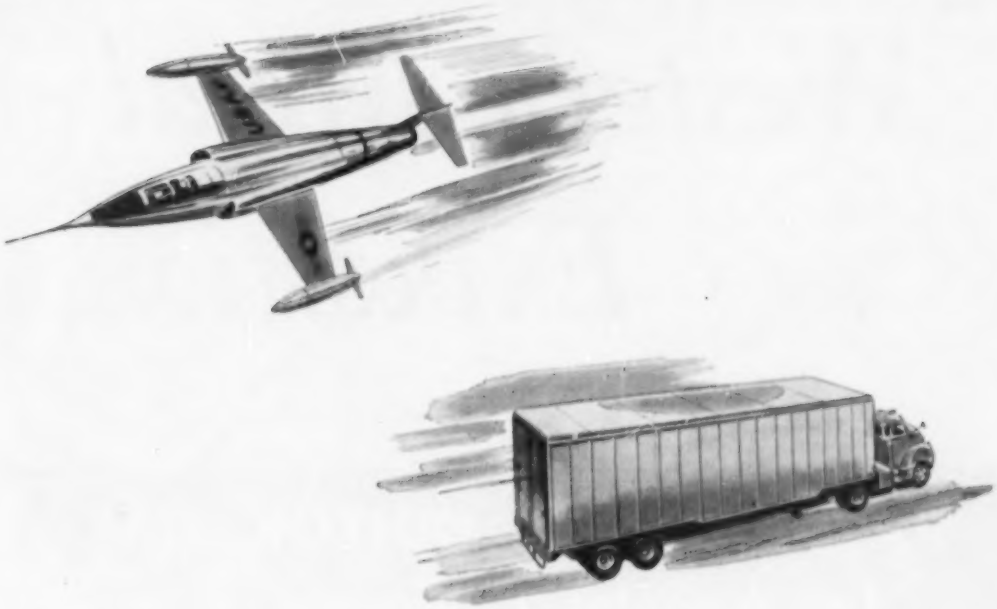

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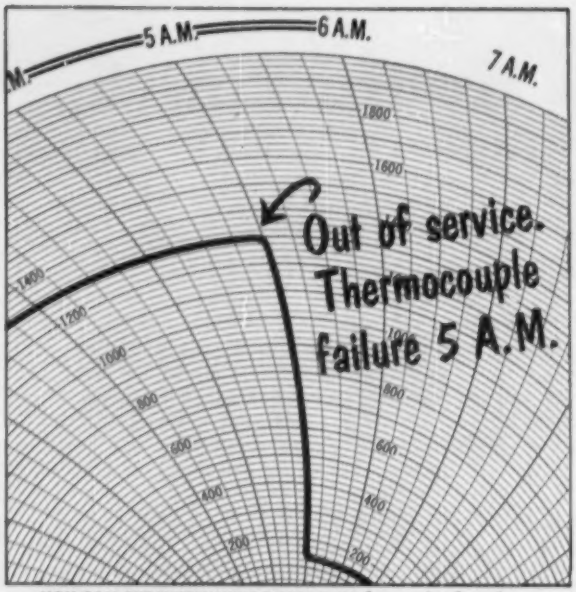

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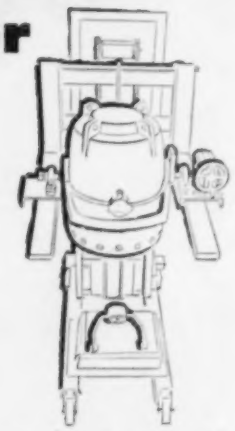

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This unretouched photograph shows deterioration of 25-12 alloy radiant tube after 10 months service.

This unretouched photograph shows radiant tube of NA22H still in serviceable condition after 78 months service in the hot zone where temperatures averaged 1850°F.

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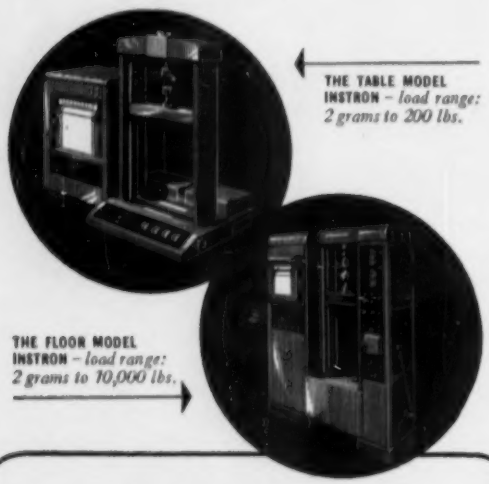

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1957

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DECEMBER

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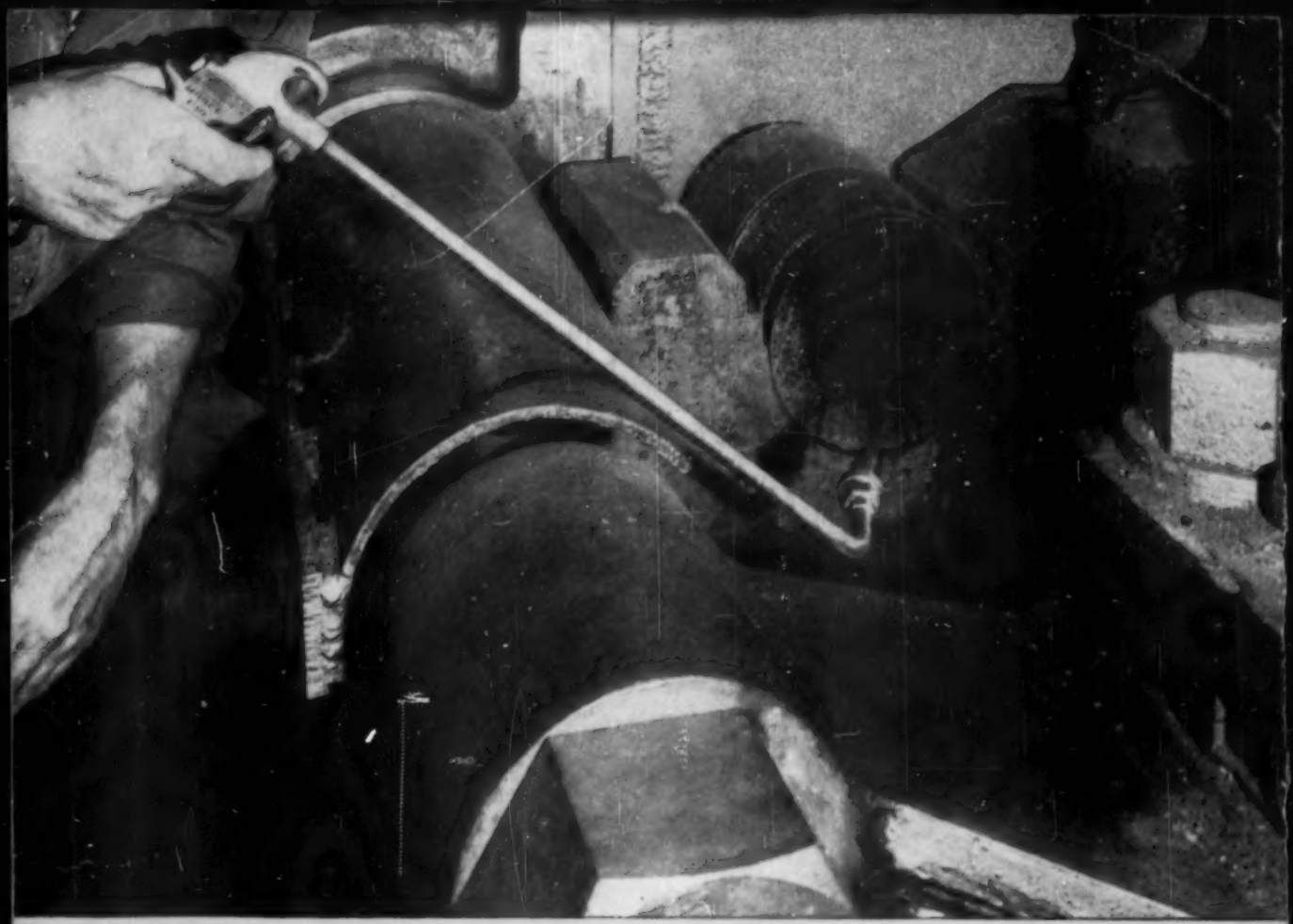

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